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Fig. I.

The Solar Spectrum.

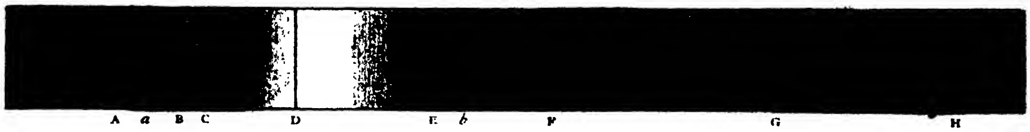
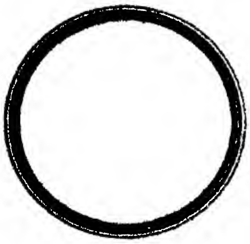
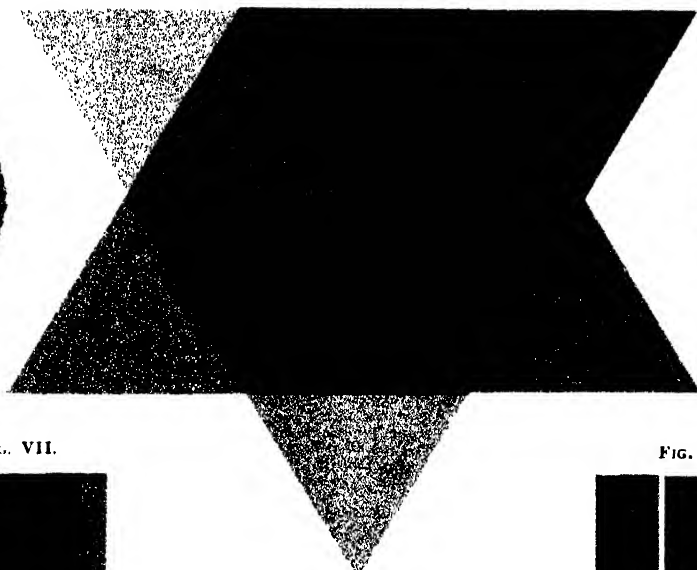


Fig. III.



Subjective Colours.

Fig. II.



The Primary, Secondary, and Tertiary Colours

Fig. IV

Colour as related to idea of Distance.

Fig. V.

Effect on Colours of Apposition.

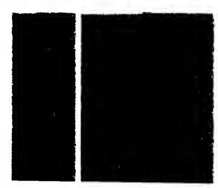
Fig. VI.

Mixture of Colours by Apposition.

Fig. VII.

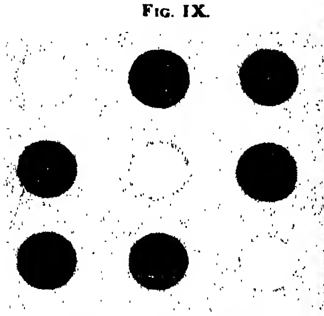
Indistinctness of Related Colours in contact.

Fig. VIII.



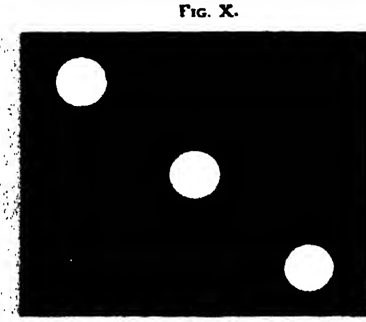
Effect of Black and White in separating Colours.

Fig. IX.



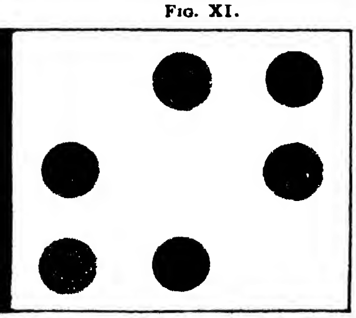
Effect of a Grey Ground on Colours.

Fig. X.



Effect of a Black Ground on Colours.

Fig. XI.



Effect of a White Ground on Colours.

See Lessons on Theory of Colour.

THE

TECHNICAL EDUCATOR:

An Encyclopædia

OF

TECHNICAL EDUCATION.

VOL. I.

CASSELL & COMPANY, LIMITED

LONDON, PARIS, NEW YORK & MELBOURNE.

INDEX TO CONTENTS.

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THE

TECHNICAL EDUCATOR:

BEING THE TECHNICAL SERIES OF "CASSELL'S POPULAR EDUCATOR."

INTRODUCTION.

BEFORE entering upon the course of lessons which we are about to lay before our readers in THE TECHNICAL EDUCATOR (which is intended to furnish a *practical* sequel to the theoretical lessons contained in THE POPULAR EDUCATOR, and to which work indeed it forms a necessary supplement), it appears desirable to state [illegible]t is understood by Technical Education, and to give [illegible]ne general idea of the system upon which it is our [illegible]tention to proceed.

Technical Education, as we have already explained in the address "To our Readers" in the concluding volume of THE POPULAR EDUCATOR, means literally education in any special art, and in this sense, of course, it is capable of almost the widest application. There is, in fact, no calling in life, no profession, vocation, or employment, from statecraft and diplomacy downwards, through the long lines of brain-work and hand-work, whose followers do not require a technical education peculiarly suited to it to enable them to pursue it with the best results to themselves and the largest amount of benefit to others. At the present day, however, the term "Technical Education" is not generally understood in so wide a signification, but it is confined to special instruction designed to enable men who live by hand labour to apply to their handicraft the leading principles of science which bear more especially upon it.

Without going to the length of giving a detailed list of all the different classes of hand-workers to whom this special kind of art instruction may be of benefit, we may at least indicate in general terms the course of instruction we purpose to adopt in these volumes. The subject which primarily affects those who would receive benefit from Technical Education is DRAWING in its practical application to the various Constructive Arts, as well as to DESIGN and ORNAMENTATION. Papers on these subjects, together with the kindred ones of PERSPECTIVE, PROJECTION, and PRACTICAL GEOMETRY, will run through the volumes of THE TECHNICAL EDUCATOR, those on TECHNICAL DRAWING for Trade Purposes embracing Drawing for Carpenters and Joiners, Masons, Metal-Workers, and several others. DESIGN will be treated under its various conditions and in its different styles, both as regards purity and correctness of form, and harmony and balance of colour. With regard to the latter portion of the subject, special information will be given in a series of papers upon the THEORY of COLOUR. The subject of DRAWING is in one branch intimately connected with that of PRACTICAL BUILDING CONSTRUCTION, which will form another portion of our series, and will treat of such points as the principles of construction generally, of scaffolding, and the strength, resistance, and applicability of different building materials.

The principles of Mechanics and Machinery have already been laid down in THE POPULAR EDUCATOR. In the present volumes we shall supplement this information by describing the practical application of these principles to the machinery, tools, and agricultural implements in ordinary use. Special papers will also be devoted to the STEAM-ENGINE, in its various applications to locomotive and mechanical purposes. A set of papers upon the principles and practice of ELECTRIC TELEGRAPHY will form a practical continuation to the information already given on that subject in THE POPULAR EDUCATOR. Other important subjects which will form part of our scheme are CIVIL ENGINEERING and the kindred sciences of MILITARY ENGINEERING and FORTIFICATION, while we shall also treat of SANITARY ENGINEERING and of what may be termed AGRICULTURAL ENGINEERING—the drainage and irrigation of land, and making of fences and roads.

In the present day no subject possesses more interest and importance than ELECTRICAL ENGINEERING, and a series of papers on it is, therefore, indispensable in a work of this character.

A portion of our space will be devoted to an account of the various ANIMAL, VEGETABLE, and MINERAL PRODUCTS used in Trade, and the processes of their manufacture from the raw material into articles of utility and ornament. Closely allied to these subjects is PRACTICAL CHEMISTRY, which will be treated of in its application to Trade Purposes and Manufactures, and also to Agriculture. The course of instruction we have thus laid down will be sufficiently comprehensive to include every branch of handicraft work; but in addition to this, some special branches of manufacture will also receive separate treatment.

We have now enumerated some of the subjects in which direct instruction will be given, and we have thought it advisable to add to them some others which will form a very interesting portion of the Work, being at the same time of a character both practical and instructive. Among these will be given descriptions of several of the PRINCIPAL SEATS OF INDUSTRY; BIOGRAPHIES OF NOTABLE INVENTORS AND MANUFACTURERS, with accounts of their work; a sketch of the PROGRESS AND PRACTICE OF TECHNICAL EDUCATION; besides other features of permanent value.

February, 28 Days.

1 **Sn.** 4TH SUNDAY AFTER EPIPHANY.—End of the Retreat and General Holy Communion at 8 a.m.

---

2 M. **Purification of the B. V. Mary.**—*Holiday.*

3 T.

4 W.

5 Th. No School.

6 F.

7 S.

8 **Sn.** SEPTUAGESIMA SUNDAY.

9 M.

10 T.

11 W.

12 Th. No School.

---

13 F.

14 S.

their economic uses, and a statement of their comparative commercial value, in order that the appliances of social life and the claims of civilisation may advance with the progress of inquiry and the diffusion of knowledge.

Energy and skill are alike taxed for the discovery of new properties in the animal, the vegetable, and the mineral kingdoms; or for the further utilisation of properties long known. A careful study, then, of the contents of a collection like that in the South Kensington Museum, together with the greater variety passing through our Custom-house from the cargoes of all nations, must be highly important, while it can hardly fail to be interesting.

ZOOLOGICAL CLASSIFICATION.

Naturalists have arranged the animal kingdom into two grand divisions, though some authorities subdivide it to a further extent in accordance with the latest results of special research. As, however, we cannot here pretend to the exhaustive treatment of the scientist, the more simple classification will be sufficient.

I. VERTEBRATA (Latin, *verto*, I turn), or vertebrated animals, having the central portion of the nervous system, or the brain and spinal cord enclosed, the former in a cavity called the cranium or skull, and the latter in a canal composed of a succession of united vertebræ, or bony segments, or, as in some fishes, of cartilage.

ORNITHORHYNCHUS, OR DUCK-MOLE OF AUSTRALIA.

The vertebrated animals are arranged in five divisions or classes:—

1. *Mammalia* (Latin, *mamma*, a teat).—Animals which possess mammary glands and suckle their young, bringing them forth alive. Examples: the monkey, ox, seal, elephant, and whale.

2. *Aves* (Latin, *avis*, a bird).—Oviparous vertebrated animals covered with feathers and organised for flight. Examples: the ostrich, an, pheasant, and eagle.

3. *Reptilia* (Latin, *repo*, to creep).—Cold-blooded vertebrated animals, covered with scales or hard bony plates, terrestrial or aquatic, air-breathing, and endowed with extraordinary powers of endurance under abstinence, or against bodily injury. Examples: the turtle, snake, crocodile, lizard.

4. *Amphibia* (Greek, *amphibios*).—Fish-like in the early period of their existence, breathing exclusively by gills, and having a two-chambered heart, finally becoming air-breathers, acquiring lungs and a three-chambered heart, losing wholly or partially their piscine character, and becoming more or less terrestrial. Examples: the frog, toad, and proteus.

5. *Pisces* (Latin, *piscis*, a fish).—Oviparous vertebrated animals having a branchial respiration, a covering of scales, and an organisation for life in the water. Examples: the sturgeon, cod, and herring.

II. INVERTEBRATA, or animals destitute of a cranium or skull and a vertebral column, comprise four sub-kingdoms, although some biologists arrange them into six groups.

1. *Mollusca* (Latin, *mollis*, soft), or soft-bodied animals, popularly known as shell-fish. Examples: the oyster, pearl-oyster, and mussel.

2. *Annulosa* (Latin, *annulus*, a ring), or ringed animals. Examples: crabs, leeches, and insects.

3. *Radiata* (Latin, *radius*, a ray), or radiated animals. Examples: the sea-anemone and red coral.

4. *Protozoa* (Greek, *protos*, first, and *zoön*, animal), or first animals. Example: the common sponge.

We now purpose to take up the various animal products in succession according to the above zoological arrangement. We begin with the highest and most useful class of Vertebrata, or the

PRODUCTS OF THE CLASS MAMMALIA.

This class comprises twelve orders, viz.:—

1. *Bimana* (Latin, *bis*, twice, and *manus*, the hand), or two-handed animals. Example: man.

2. *Quadrumana* (Latin, *quatuor*, four, and *manus*, the hand), or four-handed animals. Example: the monkey.

3. *Cheiroptera* (Greek, *cheir*, the hand, and *pteron*, a wing), or hand-winged animals. Example: the bat.

4. *Insectivora* (Latin, *insecta*, insects, and *voro*, I devour), insect-eaters. Examples: the hedgehog, mole, and shrew.

5. *Carnivora* (Latin, *caro*, *carnis*, flesh, and *voro*, I devour), flesh-eaters Examples: the lion, tiger, fox, and ermine.

6. *Cetacea* (Gr. *ketos*, a whale), or whale-like animals. Examples: the porpoise and whale.

7. *Pachydermata* (Greek, *pachus*, thick, and *derma*, skin), or thick-skinned animals. Examples: the elephant, horse, and pig.

8. *Ruminantia* (Latin, *ruminare*, to ruminate), ruminating animals. Examples: the stag, ox, and sheep.

9. *Edentata* (Latin, *edentatus*, without teeth), toothless animals. Examples: the sloth and armadillo.

10. *Rodentia* (Latin, *rodere*, to gnaw), gnawing animals. Examples: the squirrel, rat, rabbit, and hare.

11. *Marsupialia* (Latin, *marsupium*, a pouch), or pouched animals. Examples: the kangaroo, opossum.

12. *Monotremata* (signifying with one orifice or outlet), beaked, non-placental mammals. Examples: the echidna, or porcupine ant-eater, and the ornithorhynchus or duck-mole of Australia, to which country these monotrematous animals are peculiar. (*See* Fig. on this page.)

The extensive class, Mammalia, supplies us with food in the form of flesh and milk: also with fur, wool, skins, hides, horns, hair, hoofs, fats, oils, bone, ivory, etc. In some instances every part is available—as, for example, in the horse. Leather is made from the skin; the hair is manufactured into hair-cloth and bags for crushing seed in oil-mills; the flesh furnishes food for dogs poultry, and even men; the intestines, a covering for sausages; glue and gelatine are formed from the tendons · knife-handles and phosphorus from the bones; and buttons and snuff-boxes from the hoofs.

I. FURS.

We derive furs from all the orders of the Mammalia, with two exceptions—Bimana and Cetacea. Man and the whales are well

known to be smooth-skinned animals. It is, however, the Carnivora and Rodentia principally which supply the market with furs. All our furs, both home and foreign, are either felted or dressed; the former are used in the manufacture of hats, the latter as articles of clothing. Fur is one of the most perfect non-conductors of heat, and therefore, if properly prepared, makes the most comfortable clothing that can be worn in cold climates. We find the animals there provided by Nature with this substance for their own protection, and therefore man has adopted it as the most suitable clothing for himself. In the prepared state skins are called furs; without preparation, *peltry*.

The hunter, as soon as the animal is captured and killed, strips off the skin, and hangs it up to dry, either in the open air or in a warm room. If the skin is well dried and properly packed, it may be sent to any distance, and will be received in good condition; but if any moisture is left in the skin, or if it becomes exposed to damp on the voyage, putrefaction ensues, the hair falls off, and it is unfit for use so far as the furrier is concerned. A minute examination of the skins received is therefore the first thing to be done; the grease is removed by steeping them in a liquid containing bran, alum, and salt, and by washing and scouring them; and the oil is extracted from the fur with soap and soda. By subsequent treatment, each skin is tanned and converted into thin leather. It is now washed in clean water and dried, and is then ready to be made up into articles of dress.

Felting is a process by which the different kinds of hair and wool are interlaced or intertwined, so as to form a close compact texture or mat. The felting capabilities of fur depend on the peculiar structure of the hair. Hair capable of felting has its surface covered with little serratures, which may be seen with the microscope; and the felting consists in simply entangling these serratures with each other, and so matting the hairs together. Hair which is devoid of this serrated structure will not felt.

The felting furs are confined to a few animals, such as the hare, rabbit, beaver, etc. These animals have two kinds of hair: a long and coarse kind, forming their visible external covering, which does *not* felt; and a shorter, finer, and more abundant kind, which lies close to the skin, and is called the fur, and which does felt easily. When the skins are intended to be felted, these long hairs are first removed, either by being plucked out, or by very careful shearing. In the case of the beaver and rabbit, the long hair is pulled out with a short knife, the thumb of the operator being protected by a leather shield. The long hairs thus removed are of no use to the hatter, but are sold for stuffing chairs. The fur is then cut from the skin in a light fleecy mass, and the flocks are tossed about by the strokes of a vibrating string or bow, until matted together into a thin sheet of soft spongy felt; a second sheet is pressed upon it, and then a third, until the required degree of strength and thickness of felt is obtained. The following are the most important of the fur-bearing animals:—

QUADRUMANA.

The chief monkey-furs imported are those obtained from the *howlers*, the largest of the New World monkeys. They are made up into muffs.

CARNIVORA.

These animals, next to the monkeys, are the most closely allied to man in organisation. Naturalists have divided them according to their mode of progression, which depends on certain peculiarities in the structure of their feet, into three leading groups:—

1. The *Digitigrada*, or finger-walkers (Latin, *digitus*, a finger, and *gradior*, I walk), from the habit of walking on their toes. Examples: the lion, tiger, and cat.

2. *Plantigrada*, or sole-walkers (Latin, *planta*, the sole of the foot), because applying the whole or the greater part of the sole to the ground when walking. Examples: the bear, racoon, wolverine, and badger.

3. *Pinnigrada*, or fin-walkers (Latin, *pinna*, a fin or feather), having their feet well adapted for progression through the water, by an expansion of the skin or web between the digits, and also for some slight degree of progression on land. Examples: the seal and walrus.

DIGITIGRADA.

This division of the Carnivora includes the family (Latin, *felis*, a cat), so named by Linnæus, because an excellent example is furnished in the common domestic cat. These are characterised by the strong, sharp, retractile talons with which all their toes are armed; they have teeth to correspond, peculiarly adapted for destroying other animals, and for tearing, dividing, and crushing flesh. Their sight is keen, to enable them to discern their prey, and they have great power of dissembling, so as to be able to lure their victims to destruction. It is most fortunate for mankind that these formidable animals have not the instinct of sociality; otherwise, what could withstand a troop of lions or tigers hunting in concert like wolves? The most celebrated species of this genus is—

The Lion (*Felis leo*).—This magnificent animal is distributed over the African continent and the southern parts of Asia. The long flowing mane of the male gives him a majestic appearance. His courage and strength are both indisputable, but he is as genuine a cat as the tiger, and quite as bloodthirsty and cruel in his disposition. The lion skins imported into this country come chiefly from Africa.

WEAPONS OF WAR.—I.

BY AN OFFICER OF THE ROYAL ARTILLERY.

INTRODUCTION.

In order properly to appreciate the various improvements which through successive centuries have been introduced in weapons of war, and of which we see the combined results in the perfected arms with which the modern soldier is provided, it is essential first to recognise distinctly the object which weapons are required to fulfil. In this way alone can we hope to obtain a firm grasp of the relative merits of particular types and classes of arms, and of the considerations which have recommended this simplification and that modification, which have determined the rejection of one weapon and the introduction of another.

What, then, is the use and object of weapons of war? What principle has ever governed the advance of this branch of the world's industry and ingenuity? The answer to these questions is best furnished by a brief reference to the general history of the subject. The theoretical starting-point is that remote epoch when man attacked his enemy and his prey with the weapons with which Nature had provided him. We say "theoretical," because the actual existence of such an epoch is extremely doubtful, and in any case it must have been of insignificantly brief duration. That quality which distinguishes man from the brutes must early, if not immediately, have enlightened him as to the advantages to be derived from the employment of accessory means of attack or defence. By a strange contradiction, the stream of almost Satanic ingenuity which since the time of Adam or of Cain has gone on widening, and deepening, and strengthening—the tide of invention which has brought us the cannon and the rifle, the shell and the torpedo, which has improved the rude guns of the fifteenth or sixteenth centuries into the Armstrong of the present, which has changed Brown Bess into the Martini-Henry, which has developed the "infernal machine" of Fieschi into the mitrailleur of our own day—this stream took its rise in the God-like quality of reason. Man's intelligence at once prompted him to do that which was to the beasts, against whom his earliest wars were made, impossible, viz., to second his efforts by such assistance as he could draw from material resources. To weight the fist with a stone, to add force to the blow by means of a stick or club—such were the expedients at first adopted, and which we know, on the highest of all authorities, were employed in the daybreak of the world's history with fatal success. But, by degrees, that faculty which had suggested these rude auxiliary weapons, reached forward to other developments, and gave us the fashioned side-arm of definite form, the shaped weapon of stone or flint, of wood and bronze, of iron and steel. And then, as the study of the art expanded, it became obvious that a great advantage would result from the adoption of contrivances which would enable the enemy to be struck at a greater distance than hand weapons permitted; and so we got to the class of missile weapons—to the javelin, the assegai, and others, to be thrown by hand, and the projectile weapons, such as the blow-pipe, for projecting poisoned darts, the bow, the cross-bow and the sling, and the more powerful engines of

war, such as the catapult and ballista. And now we strike the track which leads more directly down to our own age. The range of these projectile weapons was so small, and their accuracy was so imperfect, while the importance of range and accuracy became so conclusively established, that the next considerable development naturally took these directions. At this point we mark the introduction of gunpowder, by which the ranges of offensive weapons and their practical importance were at once immensely increased.

With the introduction of fire-arms we mark, indeed, a new epoch, although the object remained the same—the killing or disabling of one's enemy at the greatest distance, and with the greatest ease and certainty. The art received a new impulse; the "villainous saltpetre" breathed into it a new life; and since that time men have laboured with an unfailing zest at the perfecting of fire-arms, to the gradual pushing into the background of mere hand or missile weapons. During this period the successive improvements have nearly all taken the form of some advance in the production of long-range arms of precision of increased destructiveness. The greatest distance, the greatest and most irresistible certainty of destruction—these were the two main elements of success, and the attempts to achieve success on these lines have advanced us from the blunderbuss to Brown Bess, from Brown Bess to the Brunswick rifle, from the Brunswick rifle to the Enfield, from the Enfield to the Martini-Henry. With cannon, in the same way, pressed by the same considerations, we have advanced from the rude appliances of the sixteenth and seventeenth centuries to the smooth bores which won the victories of Nelson and of Wellington, and, again, to the rifled guns of Armstrong, and Whitworth, and Woolwich. Again, from the simple round shot of an early age, or the rude and imperfect shell of the seventeenth century, we have travelled forward, always in the direction of increased destructiveness, to the shrapnel, and the segment, and the huge, far-reaching common and double shell, with their enormous charges of powder, and to the Palliser projectiles, which set at defiance the stoutest armour-plating.

But, beyond a point, precision and range lose their practical value. Where exactly that line is to be drawn it is difficult to say. Some enthusiasts would probably place it at the limits of human vision; practical soldiers, however, know that other considerations than these really determine the limits. At all events, when men had got to military rifles, which would shoot with accuracy for half a mile or three-quarters, their instinct instructed them to seek to exercise their ingenuity in another direction. To multiply the rate of fire, within the limits already attained, became the problem of the day, and the result of this movement has been the introduction of breech-loading rifles of immense variety, and many of surprising excellence.

This brief and imperfect outline of the history of the subject will enable us to note the direction in which the tide of improvement has gradually but surely set, and to recognise, in a general way, the objects which the artillerist and the rifleman have endeavoured to attain.

But it is also important to recognise the influence of other considerations besides those of achieving determinate results. War is an art essentially of practice and not of theory; and while theorists have been elaborating complex contrivances for the destruction of human life on the largest possible scale, the soldier, in his blunt way, has been ever at hand to exclaim: "C'est magnifique, mais ce n'est pas la guerre." Simplicity in warlike appliances is a necessity of their existence, which unpractised designers are apt to overlook. Economy, too, is a consideration which the soldier cannot afford to disregard. Capability of resisting rough usage, transport, exposure, and climatic changes may also be classed among the essentials of engines of war, the due observance of which limits the channel along which the military inventor must travel. In the case of warlike stores for English use, these considerations are especially important, on account of the scattered nature of our dependencies, the variety of climates to which the stores are likely to be exposed, and the certainty that, in transport to our distant possessions, they will have much rough treatment to endure. This is a lesson which inventors, unfortunately, are slow to learn. They pursue a phantom of theoretical excellence in utter disregard of the consideration that the soldier wants the real, not the ideal. They trample ruthlessly on the practical arguments which are opposed to their headlong progress, and push impatiently on one side the objections which those who know what war is venture to suggest. Even so distinguished a man as Lord Armstrong has not steered clear of this rock, and we find that, where his inventions in war *matériel* have trenched upon the province of the artilleryman proper—in his first breech-closing arrangements, for example, in his fuses, and his shells—they have all been more or less failures. When only mechanical, as distinguished from practical military considerations, were concerned, as in the structure of his guns, they have been eminently successful. To those readers who may now, or at some future time, conceive the idea of designing some weapon of war, we would give this serious advice: Whatever you may propose, be practical. Seek the advice, if you can, of some plain-spoken soldier; one who has seen service; one who knows something of the hurry and confusion and destruction of action, of the roughness of military transport; who can tell you of the rains and heats of India; who knows how clumsy are a soldier's fingers, and how little suited to ingenious refinements; one who can tell you, too, something of the brilliant failures of scores of clever but unpractical inventions, of fair hopes and extravagant promises wrecked on the first contact with the rough touchstone of practice—one, above all, who will not mince matters, but will say plainly, if need be, "Yours is the silliest and most unpractical invention which I have ever seen." He is the best friend to the inventor who speaks thus; he is the best friend also to his country, for he thus directs the inventive genius of the country into a useful course, instead of allowing it to filter itself away through vain channels into dreamland. On the other hand, we desire fully to recognise that the inventive mechanical genius and resource of England are among her native advantages, as substantial and important as her coal mines—advantages to be fostered and cherished by all means, and to be promoted by a liberal policy of encouragement on the part of both soldiers and the Government.

If the present papers should have the effect of directing attention to war material, and stimulating the ingenuity of some who may honour them with their perusal, they will have accomplished more than the writer can dare to expect. He, on his side, would fail of his duty if he did not, with all emphasis, urge those who would enter upon the difficult and precarious path of improving our war material, to be, above all things, simple and practical. As Frederick the Great said, "What is not simple is not possible in war."

In considering this subject it will be most convenient to treat first of portable arms, and then to proceed to the examination of artillery weapons.

Each of these classes—portable arms and artillery *—admits of further and almost indefinite sub-division. We will proceed to consider them separately, under their particular heads.

PORTABLE ARMS.

Under this head are included all weapons which are borne upon a man's person.

They are of two principal divisions:—

(1.) *Side-arms.*

(2.) *Fire-arms.*

(1.) Under the head of side-arms are included swords, spears, lances, daggers, bayonets, pikes, javelins, arrows, and the like. The class is really a more comprehensive one than many persons suppose. The great advances made with fire-arms must be acknowledged to tend to push such weapons as swords and bayonets into a more subordinate position. If you can kill your enemy a mile off, the prospects of his being able to close with you are evidently less than when the range of your weapons was only a few score yards. Similarly, the great increase in the rapidity of fire of modern fire-arms renders less possible a successful charge of cavalry upon an infantry line or square, and by so much reduces the value of the sabre or the lance. But these considerations, which are perfectly just in themselves, have been pushed too far by theorists, and many have hastily and improperly jumped to the conclusion that the days of the bayonet and sword are gone by. To this the experience of the Franco-Prussian war furnished an

* The classes have been placed in the above order because that order is, to some extent, historical, and indicates roughly where the most ancient and most modern contrivances will generally be found.

emphatic contradiction. It is quite clear that despite the improvements in fire-arms, hand-weapons still possess considerable importance—that they may even determine the crisis of a stubborn fight. If an obstinate enemy cannot be dislodged from his entrenchments by a musketry or artillery fire, against which his defences may afford him ample protection, he must be driven out with the bayonet, at whatever cost, and this was actually done more than once in the war already alluded to; while, although cavalry may no longer be employed to ride down infantry squares, they will still be required to sweep over the fields of battle, to complete a disorganisation already commenced, to convert a retreat into a rout, to drive home the wedge which the rifle and cannon have inserted. Here, therefore, we see a continued use for the bayonet, the sword, and the lance; and, accordingly, we find all those weapons retaining their place in the British service.

There are a considerable variety of swords in use in our army—the whole being made at the Royal Small Arms Factory at Enfield. The principal types of swords are those for the cavalry, and the navy cutlass. Of the other ten sorts of swords enumerated in the official vocabulary, the greater part are for serjeants, for Highland regiments, for volunteer non-commissioned officers, etc. Pioneers have a sword with a saw-back, which is found useful in sawing through wood, removing obstacles, and doing some of the special work which pioneers are required to perform. It is noticeable that there is a growing tendency to utilise hand-weapons for more than one purpose. This is perhaps a natural result of the decreased importance of these weapons for the particular purpose to fulfil which they were originally introduced.

We thus find that at one time a sword-bayonet with a saw-back was proposed and tried with the Martini-Henry rifle. This weapon, although it served to saw fire-wood on an emergency, and was useful for clearing away light obstacles, was found to be cumbrous and top-heavy. Therefore as the new rifle was shorter than the old Enfield pattern, a plain triangular-headed bayonet about twenty-one and a half inches long—that is, about two inches longer than the old weapon—was introduced, and is now in use in the service. A plain sword-bayonet is still used by the artillery.

Other combination-bayonets besides the one noticed above, have been proposed by some inventors; although none of them have proved any more serviceable than the one already noticed. Thus one weapon was at once a spade or trowel and a bayonet; sometimes too the bayonet was so broad and flat that it could be worn round the neck as a piece of defensive armour for the breast.

Some of the best—probably the best—swords in Europe are manufactured at Solingen, in Rhenish Prussia. Not less remarkable than the excellence of these weapons and their fine temper, is their cheapness. An infantry officer's regulation sword, with scabbard complete, can be bought at Solingen for something under £1; an artillery officer's sword for about a guinea. If purchased of good London makers, these weapons cost from £4 to £5; but the London swords, the blades for which are generally obtained from Birmingham, are in no respect better than those made at Solingen.

Visitors to the Paris Exhibition of 1867 will not readily forget the magnificent exhibition of sword cutlery furnished by M. Carl Reinh Kirschbaum, of Solingen, and which, although surpassed in decorative excellence by some of the French makers, whose highly ornamental and costly swords are rather examples of goldsmiths' than of cutlers' work, was unequalled for solid excellence and cheapness by any swords in the Exhibition. The Solingen makers prefer cast steel to damascened blades; the introduction of the iron by which the damascened appearance is produced being considered apt to soften the sword and spoil its high character, which is estimated in a great degree by the just and complete "return" of a blade after bending. All sword-makers are very far from agreed upon this point. By some it is thought that the extent to which a sword will bend is even more important than its perfectly accurate return to straightness after bending.

On this point the following remarks occur in the official report on the "Portable Arms" in the Paris Exhibition:—"The power which a blade may have of straightening again is accepted by the Solingen makers almost as a crucial test of its excellence; and when a sword is bent to a point beyond which it cannot return perfectly straight, they would almost prefer it to break than that it should exhibit softness and remain crooked. On the other hand, it is argued by some that, although it is well that a sword should straighten, it is better that it should remain permanently bent than that it should break, a bent sword being more serviceable than a broken one; and the Solingen makers are considered to lay undue stress upon the straightening qualities of the sword. As, however, the flexibility of a blade depends, after its quality, upon its transverse section, and as Solingen exhibits swords which will bend almost round a man's body, it would seem as though all the flexibility that could possibly be desired can be obtained without any admixture of iron. When a Solingen maker says he prefers that his sword —if it be bent beyond what it is capable of standing—should break rather than remain crooked, the burden of proof rests upon others of showing what useful purpose would be served by making a blade capable of bending further at the expense of some softness."

Next to the sword and the bayonet the lance is the most important of military hand-weapons. Skilfully used, the lance is a most formidable weapon; unskilfully used, it becomes a terrible encumbrance, and instead of being a weapon of defence, is really a source of danger. In India the lance is largely employed. It is peculiarly useful in pursuits or in isolated combats. A few years ago, the bamboo staff was adopted for the lance of the British soldier, as being lighter than ash. Of the head of the lance there is not much to be said, except that it should be made of a good quality of steel, and of a form favourable to inflicting a serious wound. In the British service, the triangular head is preferred to the simple conical point.

It is unnecessary, we think, to dwell at any greater length upon the subject of weapons of the sword and lance class; nor is it worth while to touch upon the assegais of Africa, the arrows of the Indian, or the javelins and spears still in vogue among some of the ruder nations. The consideration of these weapons can have no practical value. They are interesting rather from an antiquarian point of view, and as so many examples of the ingenuity of man in producing a large variety of means of attack and defence. The missile weapons—such as the javelin, the djerid, and the arrow—have completely lost their importance now that fire-arms have reached so high a pitch of development, and can be procured even by the poorest and most savage nations. Even hand-arms proper, such as swords, lances, and bayonets, have faded into a subordinate and wholly secondary position, although, for special purposes, they must ever retain a certain value. But we must hasten on to the more interesting branch of our subject, and to the consideration of fire-arms, about which we shall have much to say.

PROJECTION.—I.

INTRODUCTION.

In the Lessons in Plane Geometry given in the Popular Educator, the figures treated of are such as possess *length* and *breadth* only, these figures being considered as traced upon a flat surface, called a *plane*, thus showing their exact forms as they are really known to be.

In these papers we shall treat of the delineation of *Solids* —that is, bodies which possess not only length and breadth, but *thickness* as well; and the science by which lines are so disposed that the representation of the object may seem to stand out, or *project*, from the flat surface of the paper, is called *Projection*, which is a branch of Solid or Descriptive Geometry.

The subject may be divided into—

Orthographic Projection, by means of which objects are projected by parallel lines from given plans, elevations, or other data, the object being placed in any given position.

Isometrical Projection*, by means of which a view of an object is projected at one definite angle, a uniform scale, proportionate to the real measurement, being retained throughout.

Perspective, by which objects are drawn as they *appear* to the eye of the spectator from any point of view that may be selected.

* From two Greek words, meaning equal measures.

The present course of lessons will embrace the whole of these divisions; combining also the mode of obtaining required sections, the methods of describing the peculiar curves generated by one solid body intersecting or *penetrating* another, and the development of surfaces—that is, the construction of the exact shape to which a metal plate or other material is to be cut, so as to form or cover the required object in the most ready and accurate manner, and with the least waste—a branch which will be further considered in subsequent studies, devoted to the technical drawing adapted to the requirements of the metal plate-worker, boiler-maker, and tinman. The lessons are given in as simple a manner as possible, so that the student may be able to follow them with interest, and may be led to desire still further instruction than is here afforded; and it is hoped that the pleasure and benefit he receives from knowledge may awaken in him that spirit of enthusiasm which is the mainspring of all progress. It has been from the *want* of enthusiasm that our workmen have been content with the small amount of knowledge which they have obtained from their "mates" in the shop. It has been this apathy which has caused so many to be satisfied with the "rule of thumb" instead of the rule of *science*. It is not the province of these lessons to dilate on the natural history of enthusiasm; but our object is to warm up the spirit of our fellow-countrymen—to convince them that, if they will but study the principles of the sciences on which their trades are based, they will, with their acknowledged *manual* superiority, hold their own against the men of every country in the world. Let us, therefore, interpret *interest* in their occupation to imply *enthusiasm;* and let us translate enthusiasm to mean *that spirit which urges every man to do his work as well as it can possibly be done*, and to develop the mental powers with which his Creator has endowed him to their fullest extent, so that when he leaves the workshop of life he may, in the words of Longfellow, leave "footprints in the sands of time."

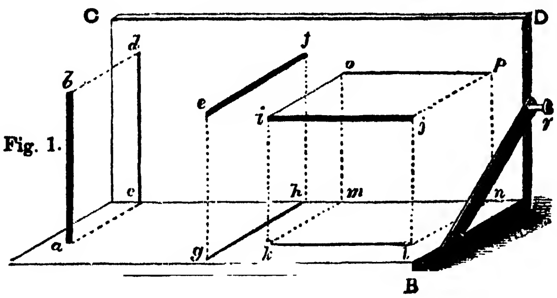


Fig. 1.

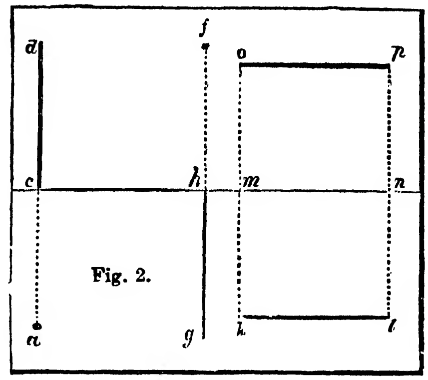
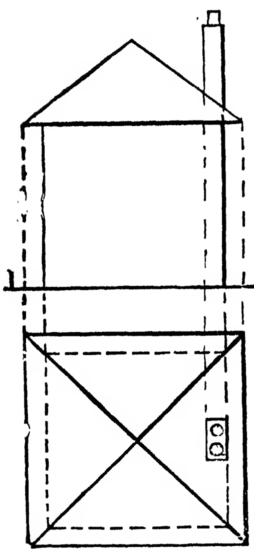


Fig. 2.



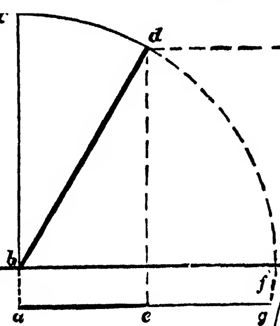


Fig. 4.

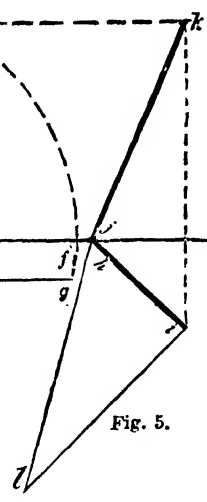


Fig. 5.

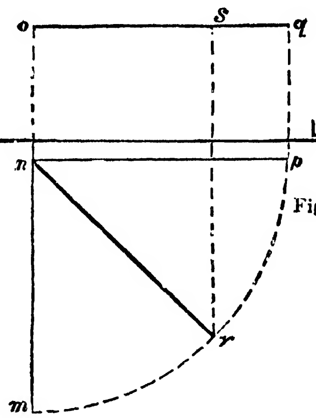


Fig. 6

ELEMENTARY PRINCIPLES OF PROJECTION.

Fig. 1.—If we place two planes or surfaces at right angles to each other, so as to form a floor and a wall, the floor, A B, is called the horizontal, and the wall, C D, the vertical, planes of projection.

THE PROJECTION OF LINES.

No. 1.—Let us take a piece of wire, and fix it in an upright position, *a b*, then the point on which the wire rests is called the horizontal projection, or *plan;* and if we carry lines directly back from its extremities until they cut the vertical plane in *c* and *d*, the line *c d* is the vertical projection or *elevation* of the wire.

No. 2.—If a wire, *e f*, be fixed at right angles to the vertical plane, the point *f*, in which it is fixed, is the *elevation*, being the view which would be obtained if the model were placed on an exact level with the eye, the point *e* being immediately opposite the spectator, so that the end only of the wire could be seen. If now perpendiculars are dropped from *e* and *f* until they meet the horizontal plane in *g* and *h*, the line uniting *g* and *h* will be the *plan* of the wire, or the view obtained by looking straight down on it. It must be remembered that in projection the visual rays are supposed to be *parallel* to each other, and not *convergent*,* as in pictorial perspective.

Further, if we suppose a wire, *i j*, to be suspended in space, perpendiculars dropped from its extremities to cut the horizontal plane will give the *plan k l;* then, if lines be drawn from *k* and *l* to meet the vertical plane in *m* and *n*, and perpendiculars be raised from these points, intersected by lines drawn from the ends of the wire parallel to *k m* and *l n*, the points *o* and *p* will be obtained, and the line joining these will be the *elevation* of the wire *i j*.

* *Convergent*, from con, *with*, and vergo, *to incline* (Latin),—arising in various points, and approaching each other until they meet.

In the model used for illustrating this lesson, the vertical and horizontal planes are connected by hinges, and are kept at right angles to each other by means of a brass loop. If now the wires be removed, and the pin, *r*, be withdrawn, so as to allow the plane, C D, to fall backwards, the two planes of projection will form one surface, separated only by the line I L (Fig. 2), and the plans and elevations will be seen in the positions in which they are placed in projection.

The line separating the two planes is called the *intersecting line*, and will be lettered I L throughout these lessons.

It must be borne in mind that the *plan* of an object does not mean merely the piece of ground *it stands* upon, but the space it overhangs as well: thus, the piece of ground on which the small lodge (Fig. 3) would stand, is represented by the dotted square in the plan, whilst the true space which the building covers or overhangs is represented by the outer square.

It will be seen that in all the figures hitherto shown the lengths of the plans and the heights of the elevations are the same as the heights and lengths of the objects they represent: thus *c d* is the same length as *a b*, and *k l* and *o p* are the same length as *i j*; but plans are not always the size, nor are elevations always the full height, of the object, both being dependent on the position or angle in which the subject to be drawn is I L. From *d* drop a perpendicular to cut this line; then *a e* is the plan of *b d* in the position in which it is now placed (viz., parallel to the vertical, and inclined at 60° to the horizontal plane); and if the movement of the wire were continued until it reached *f* (it would then be parallel to both planes), the plan would be the same line extended to *g*.

The line *b d* is said to be placed at a simple angle, because it is inclined to *one* plane, but remains parallel to the other. Let us now suppose the wire fixed in this slanting position, as far as its inclination to the horizontal plane is concerned—but if the whole hinge is made to rotate on a pivot, so that, without altering the slant, the end *d* may be turned forward—the line will then be at a *compound* angle, that is, it will be inclined, or slanting, to *both* planes.

Now it will be remembered, that although we have turned the wire round, we have not altered its slant to the horizontal plane; it will therefore overhang a piece of ground of exactly the same shape and size as it did in Fig. 4; but the position of that space will be changed. Let us now assume that, in addition to the wire being inclined at 60° to the horizontal, it is required to slant at 45° to the vertical plane. Place the plan, *h i* (Fig. 5), at 45° to the intersecting line, and draw perpendiculars from its extremities; the line from *h* will cut the intersecting line in

Fig. 7.

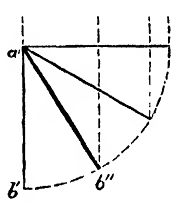


Fig. 8.

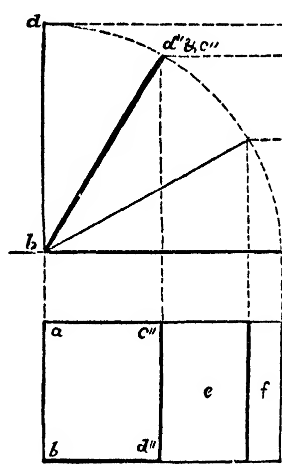


Fig. 9.

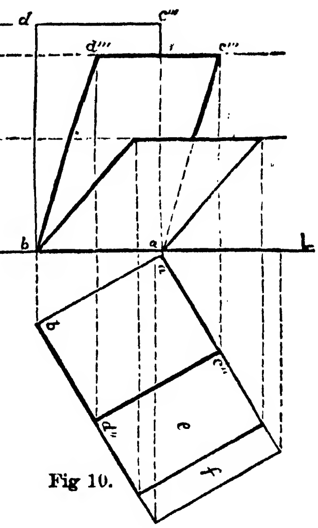


Fig 10.

placed. Before proceeding to treat of the changes which lines undergo by alteration of position, it is necessary that the terms used to define such positions should be understood, and for this purpose we again refer to Figs. 1 and 2.

Here we have the line *a b* standing upright on the floor of the model, and as its distance from the wall is the same throughout its entire length, it is said to be *at right angles (or perpendicular) to the horizontal, and parallel to the vertical plane.* The line *e f* is said to be at *right angles to the vertical, and parallel to the horizontal plane;* and it is evident that the line *i j* is *parallel to both planes.*

It will be seen that whilst the plan of a line when standing upright is a mere point (Fig. 2, *a*), the plan of the same line when placed horizontally, as *k l*, is the full length of the original. Figs. 7, 8, 9, and 10 will account for this difference, and will show how the length of the plan is dependent on the angle at which the line is inclined.

Let the original position of a wire (Fig. 4) be perfectly upright, then its plan will be the point *a*, and its elevation the line *b c*.

Now, if this wire be made to work on a hinge-joint at *b*, and if the end *c* be moved from left to right, as from *c* to *d*, the end *d* being kept the same distance from the wall of the model, the wire will still be *parallel* to the vertical, but *inclined* to the *horizontal* plane (of course it may be inclined at any angle; in this case it is at 60°).

To find the plan of this wire, draw a line from *a*, parallel to *j*, and will give the base of the line. To find its height, we must remember that, although we turned the wire round, we did not alter its slant, and therefore the height of the end *d* remains the same as it was; so that a horizontal line being drawn from *d* (Fig. 4), to meet the perpendicular drawn from *i* in the point *k*, the line *j k* will be the *projection* of the wire inclined to both planes at the required angles.

It will be seen that in this case both plan and elevation are shorter than the line itself.

EXERCISE.—To find the real length of a line when it is inclined to both planes, and its plan, *h i*, and the height of the end is given. Draw a line, *i l*, at right angles to *h i*, and make it equal to the given height. *Then the line h l will be the real length;* for the plan, the original line, and a perpendicular dropped from its end form a right-angled triangle; and this triangle, instead of standing upright, as in Fig. 4, is placed horizontally in Fig. 5; and the line *h l* will thus be found to be of the same length as *b d*. This may be illustrated by holding a set-square vertically, and rotating it on its edge until it lies on the horizontal plane; the real length of the long edge (or hypothenuse), which when the set-square was vertical was represented by its plan, *h i*, will then become visible.

Fig. 6.—Again, it has been shown that if a wire were fixed at *o*, at right angles to the vertical and parallel to the horizontal plane, its plan would be *m n*, and its elevation the point *o*; and if it were rotated on the point *n* until it became parallel to I L, its plan would be *n p*, and its elevation *o q*;

but, on the principle shown in Figs. 4 and 5, it will be evident that if the wire be rotated only as far as *r*, the elevation of it will be the line *o s*.

PROJECTION OF PLANES OR SURFACES.

The same laws which guide the projection of single lines will also govern the delineation of planes, which are flat surfaces bounded by lines. Let *a b c d* (Fig. 7) be a metal plate, the surface of which is parallel to the vertical and perpendicular to the horizontal plane, its *plan* will then be the line *a′ b′*. If now this plane be turned, so as to be at right angles to both planes, its plan—that is, the line on which it would stand—will be *a′ b′* (Fig. 8), and its elevation the line *a″ c″*, or the view obtained when looking straight at the long edge.

Now let this plane rotate on the line *a″ c″*, as a door on its hinges, until the plan reaches *b″*, then a perpendicular drawn from *b′* will give the rectangle *a″ c″ b‴ d‴*, which will be the projection of the plane, when perpendicular to the horizontal and inclined to the vertical plane, the height remaining unaltered. The other rectangles show the projections of the plane when further rotated.

Fig. 9.—In this figure the plane again rests on *a b*, its edge, *b d*, only being visible in the elevation; but this edge hides the opposite one, which is parallel to it, and therefore the points *a* and *c″* are immediately at the back of, or "beyond," *b d*. Let us now rotate the plane on *a b*, as in closing a box-lid or trap-door, then the plan of the plane will be the rectangle *a b c″ d″*; and the more the plane is lowered, the longer the plan will become, as is shown at *e* and *f*. Notwithstanding the slanting direction which the plane has assumed in relation to the horizontal plane, it still remains at right angles to the vertical plane. This is shown in the plan, where the lines *a b* and *c″ d″*, which represent the upper and lower edge of the plane, are perpendicular to I L. Let us now place the plane at a compound angle; this will be done by rotating the plan (*carefully lettered*, as in Fig. 9); then, perpendiculars drawn from each of the points, intersected by horizontal lines from the corresponding points in the elevation, will give the required projection. The process is so plainly shown in the illustration (Fig. 10) that it is believed further explanation will be unnecessary.

The student is urgently recommended not to be content with simply copying the diagrams herein given, which are merely to be considered as illustrations of principles—and thus, unless those principles be understood and applied, nothing will be gained; but he is earnestly advised to vary the form of the plane, and to project it at various angles.

MINERAL COMMERCIAL PRODUCTS.—I.

INTRODUCTION—MINERAL RAW PRODUCE.

WHILE we are indebted to the animal and vegetable worlds for a vast variety of useful products used for food, clothing, medicine, the constructive arts, and a countless number of other purposes, it is from the mineral kingdom that we obtain our coal, iron, building stone, precious metals, salt, etc. Of the uses of these and other mineral commercial products named in the annexed table, it is our purpose to give some account in this and subsequent lessons in this important subject. Mineral raw produce may be conveniently divided and considered as follows:—

I. METALS AND METALLIFEROUS MINERALS.

Iron: *Magnetic iron ore, titaniferous iron ore, red hæmatite, brown hæmatite, spathic ores, clay ironstones, other ores. Process of smelting, puddling, etc.; steel, supply of iron.* Gold, silver, quicksilver, platinum, tin, copper, lead, zinc, aluminum, antimony, bismuth, cobalt, arsenic, manganese, chromium (*with their chief ores, uses, localities*, etc.).

II. EARTHY MINERALS.

(*a*) *Coals and allied Substances.*

Coal: *Lignite, bituminous coal, steam coal, anthracite. Supply of coal.* Jet, amber, *naphtha, petroleum*, asphalt, mineral pitch.

(*b*) *Limestones, Limes, and Cements.*

Common limestones, ornamental limestones, and so-called marbles; marble, coral limestone, marl, calcareous sand, gypsum; *composition of limes, stuccoes, and cements.*

(*c*) *Silicious and Felspathic Substances.*

Rock crystal, quartz, and flint; sandstones, paving, mill, and building stones; silicious sands, rottenstone, Bath bricks, Tripoli powder, Bilin powder, berg-mehl, tellurine.

(*d*) *Igneous and Metamorphic Rocks.*

Granites: *Syenite*, mica, talc, asbestos, serpentine, basaltic rocks; *greenstone, whinstone, trap*, lava, obsidian, pumice-stone, pozzuolano, and trass.

(*e*) *Clays and allied Substances.*

Common clay, yellow, brown, and blue; kaolin and petuntse, pipe clay, fire clays, *Stourbridge clay*, fuller's earth, red and yellow ochres, slates, hone stones.

(*f*) *Earths of Sodium, Potassium, Boron, Sulphur*, etc.

Common salt, rock salt, soda, *chlorine*, alum, natron, borax, saltpetre or nitre, cubic nitre, heavy spar, celestine, strontianite, fluor spar, sulphur, *sulphuric acid*, graphite or plumbago; mineral manures, *phosphates of lime.*

(*g*) *Precious Stones.*

1. Carbonaceous: diamond.
2. Aluminous: ruby, sapphire, emerald, topaz, corundum, garnet, beryl.
3. Siliceous: amethyst, Cairngorm stone, agate, sardonyx, opal, chalcedony, carnelian, jasper, lapis-lazuli, turquoise.

1.—METALS.

IRON.

This valuable and indispensable metal is, in a variety of forms, almost universally diffused throughout the earth. It is of incalculable use in all the appliances of modern civilisation —in machinery of every description, instruments, implements, and tools of all kinds; architecture and domestic fittings and utensils; conveyance, both inland and maritime; apparatus for warming, lighting, and water supply; and even in medicine, to impart renewed vigour to the failing human frame. It occurs in all parts of the earth, in all geological formations, to which it contributes a great part of their colouring matter; it is found in all spring and river waters; and it enters into the composition of both plants and animals. It is present, too, as the principal ingredient, in the extraordinary fragments called meteoric stones, and is thus a constituent of worlds beyond our own. It can be melted and cast into moulds, softened, and hammered out into plates, drawn out into bars and wires, tempered to almost any degree of flexibility, hardened so as to scratch glass, and sharpened to the keenest cutting edge. In some of its natural forms, and also when heated to redness, iron is highly magnetic. Pure iron is white, or greyish-white, lustrous, soft, and tough, and it is one of the most infusible of metals (fusible at 3,480° Fahr.). Its specific gravity is 7·84. When beaten out it appears granular in structure; when drawn, fibrous; and to this latter peculiarity is attributed its extraordinary tenacity.

Metallic iron as it occurs in meteoric stones is usually alloyed with nickel and other metals, but its occurrence as terrestrial native iron is doubtful. There are many minerals containing iron, but of these only the oxides and carbonates are so used by the smelter; they are magnetic iron or loadstone, specular and micaceous iron ores, the red and brown hæmatites, the spathose ore and the clay ironstones.

The maximum development of iron ores appears to be in the Palæozoic rocks, the largest and richest deposits being contained in the Laurentian rocks of North America and Scandinavia; they are abundant in the Devonian rocks of Germany and south-west of England. The Carboniferous system is especially marked by the presence of interstratified argillaceous carbonates, both in America and Europe. The celebrated kidney ore of Cumberland is found in Permian strata, the Secondary rocks are rich in bedded deposits of ironstone, and the Tertiary series yields limonites.

Magnetic iron ore, or *Magnetite*, is the black oxide (Fe_3O_4, or $FeO + Fe_2O_3$), and contains 72·41 per cent. of iron. It occurs in many parts of the earth in huge masses, forming the substance of hills and even mountains, as in the mountain of Blagod, among the Urals, and in some hills of Swedish Lapland, Mexico, and Styria. In Canada magnetite is found abundantly in the gneiss and crystalline limestones constituting the Laurentian rocks; it occurs in irregular beds, often of considerable thickness, in one instance as much as 200 feet. In the State of New York this mineral occupies the Valley of Adirondack and

its neighbourhood for a mile in width and twenty miles in length. In our own country it occurs in Dartmoor, at Rosedale, and in Antrim; and it is found also in New Jersey, Pennsylvania, Nova Scotia, and parts of the East Indies. This ore is not only the richest in pure metal, but furnishes also the finest qualities. It is remarkable, however, that some veins, without any apparent chemical difference, produce finer iron than others. The produce of the mines of Dannemora in Sweden is of the finest description, and is employed in the production of the highest class of steel. Magnetic iron ore occurs chiefly in veins and fissures in diorites or dolerites, or in interstratified masses in metamorphic rocks.

Titaniferous iron ore contains proto- and per-oxide of iron, titanic acid (an oxygen compound of the metal titanium), and magnesia in variable proportions. The bar iron or steel made from titaniferous iron ore possesses unusual strength and a peculiar mottled appearance. This ore is chiefly employed with others to impart a high degree of toughness to the metal produced.

Red hæmatite is a sesquioxide of iron (Fe_2O_3), with 70 per cent. of iron. It is distinguished from the less rich brown hæmatite by its red streak, that of the latter mineral being brown in colour. Red hæmatite is known by special names, according to its different varieties:—

Specular iron ore, *oligiste*, or *iron glance*, is brilliant, hard, and distinctly crystallised. It is found in Elba, Brazil, etc.

Micaceous iron ore is scaly, crystalline, loosely coherent, and similar to graphite in structure. It is met with in South Devon.

Kidney ore is a hard botryoidal variety, devoid of lustre, such as that of Cumberland.

Red ochre is a compact, earthy, and more or less clayey variety, and is usually employed in the preparation of red and yellow ochres and umbers.

Red hæmatite occurs abundantly in England and Wales, and, being rich, is much used for mixing with the poorer ores of the Coal formations in the process of smelting. The red ore is worked in Cumberland, at Ulverstone, in the Forest of Dean, Cornwall, North Wales, Ireland, Belgium, Nova Scotia, Elba, Sweden, Missouri, and the neighbourhood of Lake Superior.

Brown iron ore or *hæmatite* consists essentially of three equivalents of water united to two of peroxide of iron, or $2Fe_2O_3 + 3H_2O$, and is compact and earthy.

Gothite is another hydrated oxide ($Fe_2O_3 + H_2O$), but it is crystallised. Both minerals are usually included in the smelter's term "brown hæmatite," and, though resembling the red in outward appearance, are distinguished by their brown streak. Bog-iron ores, and those deposited in the beds of lakes by the action of infusorial life, belong to this group of iron ores.

Brown hæmatites are largely worked in the Carboniferous rocks of England and South Wales; in the Lias of Oxfordshire, Northamptonshire, and Yorkshire; in the Lower Greensand near Devizes, and in Buckinghamshire; in Oolitic strata in France, Bavaria, Wurtemburg, Luxemburg, etc.; and in the Wealden rocks of the Boulonnais. Bog-iron ore is abundantly developed in North Germany, Sweden, Norway, Finland, and Canada.

Siderite, *spathose iron*, or *brown spar*, is a carbonate of the protoxide of iron (FeO,CO_2), or, commonly speaking, carbonate of iron. The spathic ores are sparry or crystalline, and are associated with varying quantities of carbonate of lime and of magnesia. Spathic ore, when pure, is white; but it becomes reddish on exposure to the air. It is particularly abundant in Styria, where the mountain Erzberg, near Eisenerz, is capped by the mineral to a thickness varying from 200 to 600 feet; in Carinthia and other parts of Austria; at Siegen, in the Stahlberg, or "steel mountain" (Rhenish Prussia); and in the United States (New York and Ohio). The principal English deposits are those of Weardale, in Durham; Exmoor, Devonshire; and Brendon Hill, in Somersetshire.

Clay ironstone is an amorphous argillaceous carbonate of iron, mixed with small quantities of lime and magnesia, and sometimes, as in the "black band," with bituminous matters. The poorest of the serviceable ores, they are, nevertheless, in Britain, the most important, furnishing nearly two-thirds of the total yield of iron. Being mostly connected with the Coal formations, they are cheaply worked, having in immediate proximity a plentiful supply of fuel and limestone for their reduction. There are many varieties—that called the "black band" being among the most valuable, from the ease and cheapness with which the ore may be calcined, by burning it in heaps without any additional fuel.

The ores are extensively worked in South Wales, Monmouthshire, Shropshire, Staffordshire, Yorkshire, Derbyshire, Lanarkshire, Stirlingshire, County Antrim; in Belgium, Silesia, United States, North China, Japan, India, Brazil, and Tasmania. Ireland has large deposits, which are not much worked. Clay ironstones are not confined to the Carboniferous rocks, but are extensively met with in the Lias, Oolite, and Wealden, and even among Tertiary rocks. Of this character are the rich iron district of Cleveland, in Yorkshire, and similar deposits in France.

TECHNICAL DRAWING.—I.

INTRODUCTION.

THE practice of Drawing is of such paramount importance in the mechanical arts, that in addition to the scientific principles given under the titles of Practical Geometry, Projection, Perspective, Building Construction, etc., a chapter devoted specially to Drawing applied to various trades will appear with frequent regularity in the TECHNICAL EDUCATOR. In these lessons the various methods of delineation of brickwork, timber constructions, masonry, mechanism, screws, teeth of wheels, etc. etc., will be given; the principles of construction and their application being in every case fully described.

The course of lessons will be so arranged as to combine Linear and Freehand Drawing, whilst Object and Model Drawing will be combined with Perspective and Projection in another set of lessons, the first of which appears simultaneously with this.

Each of these branches will be again divided and sub-divided, and thus, in Linear Drawing, foundations, piles, coffer-dams, wooden bridges, roofs, staircases, doors, gates, machines of various kinds, and steam-engines, with all their details enlarged, will form the subjects of lessons. Alternately with these will be given drawings of masons' and bricklayers' work, etc. etc. Mouldings, borders, scrolls, etc., the forms of tools, etc., form portions of the Freehand section; whilst practical instruction in the uses of mathematical instruments, and in the method of colouring drawings, will complete the course, which it is hoped will be found practically useful to the artisan, whatever may be his particular branch of industry.

Some description of mathematical instruments has already appeared in an early volume of the POPULAR EDUCATOR. It is therefore intended here to give instruction in the practical use of them. It must be understood, however, that it is only by *constant practice* that the power over the instruments is acquired; and the student is therefore urged to rule lines of various thicknesses, to describe articles of different sizes, and to repeat the most elementary figures, first in pencil and then in Indian ink, so as to achieve that manual dexterity and refinement which are so necessary for the mechanical draughtsman.

Let your paper be rather smaller than your drawing-board, so that the edges may not project.

To fasten the paper down, wet the back, and then paste the edges to the board; let it lie flat whilst drying. This is only necessary when the drawing is likely to be some time in hand; for exercises such as are contained in this volume, it will be sufficient to fasten the paper down by means of *drawing-pins*, which may be bought at one halfpenny each.

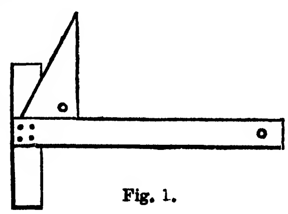


Fig. 1.

The best T-squares are those where the blade is screwed *over* the butt-end, as in the illustration (Fig. 1), as this allows of the "set-square" (or triangle) passing freely along; whilst, when the blade is mortised into the butt-end, the set-square is stopped when it comes against the projecting edge.

The T-square is to be worked against the left-hand edge of the drawing-board, and should be used for horizontal lines only—perpendiculars are best drawn by working the set-square, as above, against the T-square; for if the T-square be used for perpendicular as well as horizontal lines, the slightest inaccu-

racy in the truth of the edges of the board would prevent the lines being at right angles to each other.

There is in some cases of mathematical instruments an implement called a "parallel rule," made of two flat pieces of ebony or ivory, connected by two bars of brass. The student is not advised to use this in obtaining parallel lines, as, unless the instrument be in very good order, and very carefully used, the lines drawn will not be parallel. The best way to draw lines parallel to each other is by means of two set-squares.* Thus, let it be required to draw several lines parallel to A B (Fig. 2). Place the edge of one of your set-squares, C, against the line, and place the other set-square, D, against the first; hold D firmly down, and move C along the edge of D, and thus any number of parallel lines may be drawn; and if lines at right angles to the parallels are required, it is only necessary to hold C, and place D on it, as shown in the dotted portion of the figure.

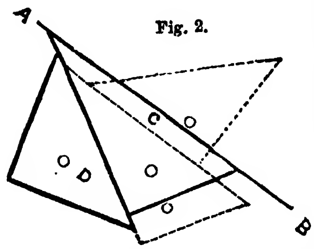


Fig. 2.

In inking the drawings, use Indian ink, not writing ink, which rusts the steel of the instruments, and so destroys their refinement. Indian ink may be obtained from twopence the stick. If you intend inking the drawings, you must work the original pencilling very lightly.

From the very onset aim at refinement, neatness, and *absolute accuracy*. Do not be satisfied if your work is *nearly* right. Try again, and, if necessary, *again;* and, with increased care and perseverance, success will be the certain result.

HOW TO USE MATHEMATICAL INSTRUMENTS.

The most important instrument is the compass. A complete pair of compasses consists of the body of the instrument and three movable parts—viz., the steel, the pencil, and the inking-legs, which are fixed in their places either by a screw, or by the end of the leg fitting accurately into a socket in the end of the shorter leg of the compass, and kept in its place by a projecting ledge, which runs in a slit in the upper side of the socket. This is by far the better method, and is used in nearly all modern instruments; its advantages over the screw form are, first, that the movable leg only remains firm in its place as long as the thread of the screw is in good order, but the very force used to tighten the pressure wears the thread away, and then the leg shakes. The consequence of this can be very well imagined, when we remember that one of the leading purposes of compasses is to draw circles, for unless the leg be absolutely firm the circle will not be true, and the point of the pencil or inking-leg will not meet the starting-point, and so an ugly break will be caused; and, secondly, that the screw, being but small, is very liable to be lost.

Be careful that in drawing the movable legs out you do not wrench or bend them from side to side, with the view of getting them out more easily, for by that means you will widen the socket, and cause the instrument to work inaccurately: the proper way is to draw the leg *straight* out.

The steel point is used when distances are to be accurately measured or divided, and therefore compasses which have both points of steel are called "dividers." A pair of these is found in most cases of instruments.

The pencil-leg is used for drawing arcs, circles, etc. Be careful that you keep it exactly the same length as the steel one; this is accomplished by drawing the pencil out a little after each sharpening. In very old-fashioned instruments the pencil is held in a split tube, which is tightened around it by means of a sliding ring; but in those of modern make a short split tube is placed at the end of a solid leg, and the cheeks of this "cannon-leg" are tightened by a screw. This is by far the better construction, as by its means the pencil is not only more firmly held, but the points of the compass may be brought more closely together than in the older form.

The use of the inking-leg (as its name implies) is to repeat the pencil-work in ink; the ink must be *Indian* ink, as already mentioned, and it is advisable to mix a small quantity of indigo with it, as otherwise it has a tendency to turn brown. When you mix the Indian ink, do not rub it very hard, as by that means you roughen the edges, and break off small pieces—they may be small indeed (and do we not frequently find failures caused by very trifling obstacles?), but they work between the nibs of the pen, and cause roughnesses and irregularities of thickness which materially damage a drawing.

On examining the inking-leg, you will find a joint in it. The purpose of this is to enable you to bend the leg at that point, so that the part which contains the ink may be kept perpendicular to the surface of the paper whilst describing a circle, for if the inking-leg were kept straight as the steel one, when the compass is opened to any extent, only *one* of the nibs (the inner one) will touch the paper, and thus the outer edge of the circle drawn will be ragged and rough. In drawing circles, be careful to lean as lightly as possible on the steel point, so that your centre may not be pricked through the paper, for then, as each concentric circle is drawn, the hole will become larger, until all chance of following the exact curve will be lost, and when you come to ink the drawing you will find the difficulty still further increased. "Horn centres" are sometimes used. These are small circular pieces of horn with three needle-points fixed in them; one of these may be placed over the centre on the paper, and pressed down; the horn being transparent, the centre-point will be visible through the small plate, and the steel point of the compass may be placed exactly over it. This is all very well in large drawings, and where the circles to be drawn are at some distance from the centre; but where numerous small circles, immediately surrounding the centre, are required, as in the projections of the sections of cones, the horn plate is useless, as it will cover some of the space on which circles are to be drawn; and further, the point resting on it is raised above the surface on which the other is working, and in small circles this will be a disadvantage. The student is therefore reminded of the old adage, "Prevention is better than cure," and he is assured that if from the outset he endeavours to *lean* lightly on the instrument, practice will soon place him beyond the necessity for the aid of the horn centre. The following hints will be found useful:—

1. See that the steel point of your compass is *round*, and not triangular, which latter form opens the little hole far more than the point would if it were round.

2. See that this point is not *too* thin; it should be rather a blunt point than otherwise, only just sharp enough to prevent it slipping away from the centre.

Should either of these two faults exist, they may be easily remedied by drawing the point a few times over an oil-stone, remembering to keep turning it round whilst moving it along.

3. Hold the compass loosely between the *thumb* and *forefinger* only, allowing the instrument to rest with equal weight on both points, and merely using the finger and thumb to support and guide it.

When a circle is required of a larger radius than can be reached with the compass in its usual form, a "lengthening-bar" is used. This is an extra brass rod, which fits into the socket in the leg of the compass, and has at its other end a socket into which the end of the pencil or inking-leg fits. This forms a pair of compasses with one leg very much longer than the other, and which is, therefore, rather awkward to manage. Here again the student is reminded that the pencil-leg and inking-pen must be bent at the joint, so that they may be perpendicular to the surface of the paper.

The full-sized compass is, however, not well adapted for drawing small circles, and therefore a complete case of instruments contains the bow-pencil and the bow-pen. These are simply small pairs of compasses, the first of which has a pencil and the other an inking-leg. These will be found very useful, and may be purchased separately if not in the case.

For still smaller purposes, "spring-bows" are used. These constitute in themselves a small set consisting of dividers, pencil, and inking-bows. The legs, instead of being united by a hinge-joint, are made in one piece, so as to form a spring, which by its action tends to force the points apart; they are then acted upon by a nut, which, screwing upon a bar fixed in one leg and passing through the other, closes the legs in the most minute degree possible. These will be found of immense

* Get two set-squares (about sixpence each), the one having angles of 45°, 45°, and 90°, and the other 30°, 60°, 90°.

service in the higher branches of mechanical and architectural drawing, where very small arcs and circles are required, as in the delineation of the teeth of wheels, mouldings, and other architectural details.

Another important instrument is the drawing-pen, which is something like the inking-leg of the compasses already described; it is, however, generally smaller in its nibs, and is fitted on to an ivory or ebony handle. The ink should be placed between the nibs by means of a camel's-hair brush. The pen should be held *nearly upright*, with its flatter side next to the rule, the end of the middle finger resting on the head of the screw. Before you ink any line of your drawing, be careful to try your pen on another piece of paper, in order that you may ascertain whether the line drawn by the pen would be of the proper thickness, and if not the pen may be adjusted by means of the screw, which acts in a way similar to the screw on the spring-bows already described. Before putting your inking-leg or drawing-pen away, be sure to wipe it well, and finally to pass a piece of paper between the nibs, so as to remove any ink that may have dried, or any grit which may have been deposited.

The rule, or straight-edge, which you use when inking your lines, must have a bevelled edge; and further, the bevel must be turned *downwards towards the paper*. This will avoid any smearing which might occur if the edge of the rule were to touch the paper whilst the line is wet.

Scales of different sorts are used in mechanical and architectural drawing; but as the subject of the present lesson does not necessarily involve working "to scale," the uses and construction of these will be found appended to the lessons on the above-named sections of scientific drawing.

The protractor, used in measuring and constructing angles, is described, and its uses explained, in the lessons in Practical Geometry (POPULAR EDUCATOR, Vol. I., page 113); repetition here is therefore unnecessary, and we proceed to mention what are called "French curves" (Fig. 3). These are rules cut into an almost endless variety of shapes, one of which is here shown: they are used in inking curves. To do this, you must turn your French curve about, until some part of it corresponds with the form already drawn in pencil, which may then be repeated in ink, the pen being guided by the French curve. If you cannot find any portion of your rule which will correspond with the whole of your pencilled curve, draw as much of it as you can, and then find the remainder at some other part of your French curve, or on another one. As these useful implements may be had in innumerable patterns, at a very moderate price, the student is advised to provide himself with two or three of them; but the writer wishes it to be plainly understood that he does not imply that by means of French curves freehand drawing may be dispensed with. On the contrary, he urges this practice on all students; for there is such variety of form in drawing, that no mechanical means can possibly supersede the necessity for the accurate and refined education of the eye which is obtained by that study; and further, a little practice will enable students to draw many curves by hand in less time than it would take them to find their places on the French curve.

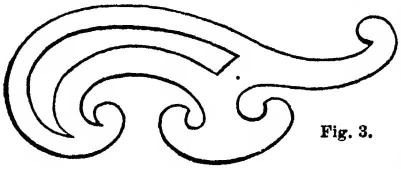


Fig. 3.

AGRICULTURAL CHEMISTRY.—I.

BY SIR CHARLES A. CAMERON, M.D., PH.D.,

Professor of Hygiene in the Royal College of Surgeons, Ireland; Analyst to the City of Dublin; Honorary Member of the New York State Agricultural Society, etc. etc.

CHAPTER I.—ON THE ELEMENTARY CONSTITUENTS OF PLANTS.

DURING recent years Agricultural Chemistry, like most of the other branches of experimental science, has made great and permanent progress. Not many years since it was regarded as a mere philosophical pursuit, which, however interesting the abstract truths revealed by it might be, afforded no useful information for the benefit of the practical farmer. Some forty years or so ago, that distinguished agriculturist, Mr. Pusey, stated that husbandry was only indebted to Chemistry for a receipt for making bone manure and a suggestion to utilise flax-steepings as a fertilising agent. However unfounded such assertions may have been when they were made, it is now generally conceded that Chemistry has conferred the most important and lasting benefits upon agriculture. It has thoroughly investigated the composition of plants; it has shed a flood of light upon those wonderful processes by which the vegetable mechanism organises into the most complex substances the lifeless mineral matters furnished by air, soil, and water; and it has discovered inexhaustible sources of fertilising materials, with which the exhaustion of our heavily-taxed fields may be indefinitely postponed. By its aid farmers are protected from fraud in the purchase of artificial manures and "artificial foods" for cattle. These are but examples of the benefits which Agricultural Chemistry has conferred upon the cultivator of the soil; and those who would aspire to be really enlightened agriculturists should not remain ignorant of a science so intimately affecting their pursuit.

In the following chapters we purpose describing the chemical history of the vegetable creation, in so far as it is of interest to agriculture. We shall endeavour to show how the plant grows, of what materials it is composed, and by what means its food is absorbed; and we shall point out the conditions which, according to both theory and practice, are found to be most favourable for the full development of the cultivated plants. Finally, we shall consider the means by which vegetable substances are re-organised into still higher combinations of matter—into the meat, milk, and butter which constitute so large a portion of the food of man. At present the Chemistry of the feeding-house is of equal importance with the Chemistry of the field.

The solid crust of the earth, so far as it is accessible to our research, the atmosphere which surrounds our globe, the waters which cover so large a portion of its surface, the innumerable vegetable forms which clothe and adorn the world, and the animals which find subsistence on its broad bosom, all have formed the subject of chemical investigation. Minerals, vegetables, animals, all are found to be composed of a comparatively small number of substances, termed *simple bodies*, or *elements*. Chalk is a compound mineral substance. By analysing—that is, by decomposing—it, two other substances, termed lime and carbonic acid gas, can be extracted from it. By a further analysis, lime is resolvable into a white metal, called calcium, and a gas termed oxygen; whilst from carbonic acid gas a solid substance—carbon or charcoal—and oxygen gas are obtainable. Chemical analysis shows us, therefore, that the compound mineral substance chalk is proximately a compound of lime and carbonic acid, and ultimately constituted of carbon, calcium, and oxygen.

Carbon, calcium, and oxygen are regarded as simple, or elementary substances, because up to the present no chemist has succeeded in decomposing them. Whilst we can extract from chalk, oil of vitriol, nitre, bones, starch, flesh, and thousands of other articles, from two to nearly a score of different kinds of matter, we fail in procuring from oxygen anything save oxygen, from calcium anything save calcium, or from carbon any substance except carbon.

There are known to exist sixty-three kinds of matter which resemble carbon and oxygen in being undecomposable. These are the raw materials with which Nature builds up her multitudinous structures. Some of them are found in a free or uncombined state—gold, oxygen, and nitrogen, for example—but the great majority always exist in combinations. Water is a compound of two elements—oxygen and hydrogen; oil of vitriol contains three—namely, oxygen, hydrogen, and sulphur; alum is composed of four—aluminum, potassium, sulphur, and oxygen. A large proportion of the elements occur in very minute quantities, and at present we know not the functions which they perform in the economy of Nature. Four simple substances—oxygen, hydrogen, carbon, and nitrogen—constitute the atmosphere, water, nearly half the weight of the crust of the globe, and by far the greater part of all animal and vegetable substances. About twenty-four of the elements form the familiar objects of every-day life, and of these the greater number are found in the organic kingdoms of Nature. The

following elementary bodies have been found in vegetable substances, but some of them are only occasionally and merely accidentally present :—

ELEMENTS FOUND IN PLANTS.

Non-Metallic Elements.		*Metals.*	
Oxygen		Potassium	
Hydrogen		Calcium	
		Magnesium	
		Iron	
Sulphur		Sodium	*Essentialness doubtful.*
Phosphorus		Lithium	
Silicon		Manganese	
Chlorine	*Essentialness doubtful.*	Cæsium	
Iodine		Rubidium	
Fluorine		Copper	
Bromine	*Non-Essential.*	Lead	*Non-Essential.*
		Arsenic	
		Zinc	
		Titanium	
		Barium	

Oxygen is a colourless, odourless, flavourless gas, about eight hundred times lighter than water. It exists free in, and constitutes about one-fifth of, the atmosphere. Eight-ninths of the weight of water and more than one-third of the crust of the earth are made up of this element; and it enters largely into the composition of animals and plants. This gas plays a prime part in the processes of combustion and respiration, the decay and dissolution of organic matter, and the decomposition of rocks.

Nitrogen in a free state constitutes four-fifths of the atmosphere. In combination with other elements it forms the important manurial agents, ammonia and nitre. It is a constituent of a numerous class of organic bodies, termed *nitrogenous* or *albuminous*. In a free state, nitrogen cannot be burned, neither does it support combustion or respiration. Its chief function is to moderate the action of the atmospheric oxygen, which, in a pure or undiluted condition, would act too energetically in the processes of respiration and combustion. Nitrogen is without colour, flavour, or odour, and is a little lighter than oxygen.

Hydrogen is a colourless, odourless, and flavourless gas, fourteen and a half times lighter than atmospheric air, and by far the least ponderable form of matter in Nature. It is very rarely found free. Hydrogen is inflammable, producing water by its combustion in air or oxygen. This element is an important constituent of plants, and is abundantly present in fats, oils, petroleum, and resins.

Carbon is a solid body, which, in a crystalline state, constitutes the most costly substance in commerce—the diamond. Lampblack, charcoal, coke, anthracite, and blacklead are essentially carbon. At the highest attainable temperature, this element remains infusible so long as it does not combine with other elements. Heated to redness in presence of oxygen, it unites with that element, and produces carbonic acid gas. Carbon is the characteristic element of organic bodies, as it is invariably found in every substance elaborated under the influence of the vital powers.

Sulphur is a yellow, inflammable solid, twice the weight of water. It occurs both free and combined, but much more abundantly in the latter state. Iron pyrites, gypsum (plaster of Paris), and sulphate of barium contain sulphur. Certain compounds of sulphur with oxygen and metals are termed sulphates; and some of these substances occur in soils, and furnish plants with the small proportion of sulphur which they require.

Phosphorus is an extremely inflammable substance. In colour and consistency it resembles white wax. It is seventenths heavier than water. Exposed to the air, it unites slowly with oxygen, forming a compound termed phosphorous acid; rapidly burned, it produces another compound with oxygen, which, under the name of phosphoric acid, is familiarly known to scientific agriculturists. This element is so inflammable that it cannot be handled without danger, and must be preserved under water. Phosphorus is never found free. In soils it occurs chiefly in the form of phosphate of calcium (a compound of phosphorus, oxygen, and calcium), but even the most fertile land seldom contains more than a half per cent. of this compound. The amount of phosphorus in whole plants probably varies from about a fourth to less than a tenth per cent.; and the proportion of phosphoric acid compounds in vegetable ashes to from 20 to 40 per cent. Sulphur compounds are less abundantly present.

The six non-metallic bodies which we have described are invariably present in plants, and they are indispensable to vegetable existence. When a plant is burned, its carbon, uniting with oxygen, passes off under the form of carbonic acid; and its hydrogen, combining with oxygen, is dissipated in the condition of water. The nitrogen in general combines with hydrogen, and produces ammonia, the "volatile alkali;" but occasionally a portion, or perhaps the whole, of the nitrogen, uniting with carbon, forms cyanogen, which generally remains as a solid ingredient of the incombustible part of the plant. The phosphorus and sulphur are, by combustion, generally converted into solid substances fixed in the fire; but occasionally a little of the sulphur may be dissipated in the form of sulphurous acid.

The substances which remain after the combustion of the plant are termed its mineral or inorganic constituents, or its ashes. They contain phosphorus, sulphur, carbon, and oxygen (in an incombustible form, combined with metals), and the metals potassium, calcium, magnesium, and iron, besides other elements, the essentialness of which is open to doubt. There are also occasionally present elements which can hardly be regarded as other than accidental impurities.

Potassium is a silvery-white metal, lighter than water. It rusts or oxidises the instant it is exposed to the air. In contact with any fluid containing oxygen, it burns with great brilliancy, evolving a rich violet light. In order, therefore, to preserve this metal, it must be covered with a layer of naphtha, a liquid which contains no oxygen. A compound of potassium with oxygen is well known under the term potash, or potassa. Potassium salts are very abundant in plants, constituting often more than half the weight of their ashes. We have made numerous attempts to grow plants in artificial soils destitute of potash, but they invariably failed, except in one instance, where rubidium, a metal which very closely resembles potassium, appeared to have been substituted for potassium. Under ordinary circumstances, however, potassium salts must be abundantly supplied to plants.

Calcium is a white metal, the oxide (oxygen compound) of which is common lime. Chalk, marble, limestone (three forms of carbonate of calcium), and gypsum (sulphate of calcium) are calcium compounds. Lime constitutes from 10 to 20 per cent. of the mineral part of plants.

Magnesium is a light white metal. It burns at a high temperature, evolving an extremely brilliant white light. Its oxide is the well-known earth magnesia. In the ashes of the seeds of plants, especially of the cereals, magnesia is abundantly present, sometimes amounting to 12 per cent. In the ashes of the whole plant, however, it seldom exceeds 4 or 5 per cent.

Iron, when pure, is a whitish metal, about seven times heavier than an equal volume of water. It unites with oxygen in four proportions, producing ferrous oxide (protoxide of iron), ferric oxide (per- or red oxide), ferroso-ferric oxide (black or magnetic oxide), and ferric acid. Iron, we have no doubt, is an indispensable ingredient of plants. Kekule detected 3 per cent. of ferric oxide in the ash of gluten from wheat, and Gorup-Besanez found 68 per cent. in the ash of the fruit envelope of the *Trapa natans*. Knop could not get maize to grow when utterly deprived of iron. In general, the amount of ferric oxide found in the ash of plants is under 1 per cent., and proportions exceeding that amount are probably useless.

Sodium is a whitish metal, very little lighter than water. It resembles potassium in many respects, but it does not quite so rapidly tarnish as that metal. Its oxide is termed soda (sodic oxide), and its compound with oxygen and carbon is the well-known carbonate of soda—in modern chemical language, sodic carbonate. Common culinary salt is a compound of sodium with chlorine. Here we should explain that none of the metals, except small quantities of iron, found in plants occur in an uncombined state in Nature.

Although sodium compounds are generally, and often very largely, present in plants, yet we are quite satisfied that this metal is neither indispensable nor useful to vegetables. The results of the experiments of Knop, Nobbe, Peligo, Siegert, and other chemists sustain this view. Our own experiments, con-

ducted during several years, and performed with various species of plants, lead to the conclusion that sodium compounds are not requisite for the full development of plants (see *Chemical News*, May and June, 1862). On the other hand, Stohmann, the Prince of Salm-Horstmar, and other investigators, assert that sodium compounds are indispensable to plant life; though they have to admit that only the merest traces are often present in healthy and fully-matured plants. It may be said that as sodium compounds (common salt, for example) are indispensable to animal life, Nature would have furnished a sufficient supply of it, as well as of the other principles of food, through the agency of the vegetable kingdom. It must, however, be borne in mind that, with the exception of water, common salt is the only mineral food which animals use; for every other food substance is, directly or indirectly, derived from plants. If Nature intended that salt should be an indispensable constituent of vegetables, animals would not have been endowed with an instinctive longing for the mineral form of that substance.

Lithium, cæsium, and rubidium are three metals allied (especially the latter two) to potassium. They are widely diffused throughout Nature, but they occur in excessively minute quantities. We have found them in several vegetable substances, but they are not invariably present, and in all probability they are not essential ingredients of plants. Salm-Horstmar, however, believes lithium to be useful in the flowering of certain plants. The remarkable resemblance between potassium and rubidium and their compounds renders it probable that the latter might be capable of replacing wholly or partially the former as an ingredient of plants.

Manganese is a metal somewhat allied to iron, and often found associated with the latter. Salm-Horstmar believes the oxide of manganese to be an indispensable ingredient of plants. Such, however, is not our opinion, for we have often found whole plants completely free from even traces of this substance.

The metals aluminum, barium, copper, lead, arsenic, zinc, and titanium have been detected in plants, but their presence therein must have been purely accidental.

The non-metal, silicon—or rather its compound with oxygen, silica—is invariably found in all plants grown under natural conditions. Sachs, Nobbe, Knop, Siegert, Rautenberg, Stohmann, Kühn, Birner, Lucanus, and others, have notwithstanding, grown plants of various kinds with perfect exclusion of silica, and apparently without injury to the plants. Pierre has proved that the common opinion, attributing the "laying" or "lodging" of corn to a deficiency of silica in the straw, is not founded on facts. It appears probable that, if silica be really requisite for plants, a very small proportion of it only is necessary. Silicon is a chemical curiosity, never being found in a free state. It occurs either as an olive-brown powder, or in the form of very hard brownish crystals. Its compound with oxygen is termed silica, silex, or silic acid. Rock-crystal is very pure silica; in a less pure state silica exists as quartz, jasper, agate, and flint. Most rocks and soils are largely composed of silica.

Chlorine gas is a yellowish-green, non-metallic body, possessed of a powerful and disagreeable odour. It is twice and a half the weight of atmospheric air. The bleaching and disinfecting properties of this gas—and of its compound, chloride of lime, or bleaching powder—are well known. Chlorine, united with potassium or sodium, is rarely, perhaps never, altogether absent from plants. Except in the case of marine and sea-side vegetables, it seldom constitutes more than 1 per cent. of the ashes of plants. Many of the most distinguished agricultural chemists assert that chlorine is not one of the necessary ingredients of cultivated plants.

Iodine is a black, solid non-metal, about five times as heavy as water; its odour somewhat resembles that of chlorine largely diluted. Its vapour possesses a splendid violet colour. In seaside plants it is found in somewhat large proportions, and it is prepared from the ashes of sea-weeds. It rarely occurs in cultivated plants, and even in the case of marine vegetables we believe that it is not indispensable.

Fluorine (a non-metal, as yet not satisfactorily isolated) is believed by Salm-Horstmar to be indispensable to vegetable life. It is, however, certain that the quantity of this element hitherto found in plants has been quite insignificant.

Bromine (a liquid resembling in its chemical relations chlorine and iodine) has been detected in plants; but there can be little doubt as to the accidental nature of its occurrence in the vegetable kingdom.

With the exception of sulphur, all the non-metals found in plants exist naturally in combination with other elements, and it is only by means of the chemist's art that these elements have been exhibited to us in their free or uncombined state.

The average amount of carbon in dried plants is about 47 per cent.; of oxygen, 42 per cent.; of hydrogen, 6 per cent.; of nitrogen, 2½ per cent.; and of ashes, 2½ per cent.

TECHNICAL EDUCATION AT HOME AND ABROAD.

I.—INTRODUCTORY—ON THE ADVANTAGES OF TECHNICAL INSTRUCTION.

BY SIR PHILIP MAGNUS.

In the following series of papers it is proposed to treat of a very wide and interesting subject. A few years ago only, there would have been very little to say on one division of the above heading, viz., Technical Education at Home; but of late years considerable progress has been made in the establishment of technical schools in this country, and although the sketches of foreign institutions which will appear in these papers will show how far ahead of us are the French, the Germans, and other nations in the provisions they have made for the technical instruction of all classes of persons occupied with industrial work, still we have reason to be satisfied with the progress in this direction that has recently been made, and with the indications of further progress that is likely to be made before many years are passed.

In considering so large a subject as "Technical Education at Home and Abroad," it is necessary to lay down some limits within which the subject shall be treated, and some easily intelligible scheme of dealing with it. Unless this is done, the reader will take away with him a confused idea of the object and purpose of the several institutions to be described; of the methods of instruction adopted; and of the relation of the school to the industry it is intended to benefit. I propose, therefore, to divide the subject into two parts, and to consider first of all some of the principal institutions in this country which provide technical instruction, and afterwards to describe some of the typical and more important schools and colleges abroad. And in doing this I do not propose to adopt a purely geographical classification, which would involve a considerable amount of repetition, since different countries have very similar establishments; but rather to group together schools of the same kind, wherever they may be found, or to indicate, as far as the results of my observation enable me, their several advantages and disadvantages. Greater interest, too, I am inclined to think, will be attached to these notices by describing visits actually paid to some of these establishments, and by giving the views of some of the professors and teachers, as ascertained in conversation with them, than by any account, however full of particulars and details, of the courses of instruction as derived from the published programme of the school. These particulars, however, will also find a place in the following papers.

Now, although much has been written on the question of technical education, and although foreign institutions have been carefully studied, and speeches and lectures without number have been delivered on the subject, considerable misapprehension still exists in the public mind as to what is meant by technical education, and as to the relation it bears to apprenticeship or trade instruction. An Englishman going into many Continental technical schools would exclaim, "But this is not technical instruction; it is only ordinary science-teaching, such as a boy might get in any modern school!" Again, there are other schools that he might enter, in which he would find boys chipping and filing for several hours in the day, busy at the anvil or at the forge, or tending an engine, and he might be disposed to remark, "Could not these boys equally well, or better, learn their trade in a trade shop, and why is it better to be apprenticed to a school-teacher than to an ordinary master?"

In this country we are continually met by a number of unsolved problems connected with technical education, to which it may be well incidentally to make reference in these papers, showing that people are not yet agreed as to what is really meant by technical education, nor how it can be best provided. Gradually, however, certain principles are being evolved, which probably, as time goes on, will be accepted as educational axioms. Thus, it is now almost generally acknowledged that in any industry in which goods are manufactured on a large scale, and in which machinery is consequently employed, a man cannot become an efficient workman by any amount of technical instruction which does not include actual practice in the shops, where work has to be done against time, and where the division of labour is extensively carried out, and every contrivance is introduced for substituting machines for hand labour.

Again, it may be affirmed that all technical instruction presupposes a good primary education, and that its chief elements are skill in drawing and a knowledge of the first principles of physical science. Here, then, we seem to stand on solid ground; and the value of many an effort to promote technical instruction may be tested by its agreement or disagreement with these general principles. For instance, the poorer artisans of this country are generally too anxious to anticipate the earnings of their children, and remove them from school at too early an age, in order that their small wages may supplement the family income, forgetting the principle that a good elementary education is the basis of all technical instruction, and that the progress and advancement of these children will be checked and their permanent wage-earning capacity lessened by this short-sighted policy. Equally necessary is it to keep this principle in view in considering the attempts that are sometimes made to teach the mere applications of science to special industries, without previous instruction in the elements of science, which must be known before the applications can be understood. And so, too, as regards Art—there are those who think they can be taught to design for a trade before they have learnt to draw, to say nothing of the numbers of persons actually engaged as wood-engravers and wood-carvers, and doing their work, badly enough, through want of adequate previous study of drawing and modelling.

The Education Act of 1870, with its subsequent improvements, in giving to the poorest classes a sound elementary education, has done much towards rendering technical instruction possible; and it is perhaps a significant fact that in the year 1880, ten years after the passing of this Act, when some of the children educated in the new Board schools had grown up and were beginning to realise the want of further instruction, especially directed towards the explanation of the problems connected with their ordinary work, the City and Guilds of London Institute for the Advancement of Technical Education was incorporated.

To the possible improvements that may be introduced into the Elementary Education Act, with the view of making the instruction bear more directly upon the future careers of the children, it is not necessary here to refer. Later on, the opportunity will be afforded, in considering primary education in other countries, to discuss the advisability of introducing other subjects into the curriculum of the primary schools, and of showing how room may be made for these additions. Here, it is only necessary to remark, that the general intelligence of a workman depends very much upon the elementary education he has received; that one of the great differences between the system of primary instruction here and abroad, is that in Germany and Switzerland children are compelled to remain at school till they are at least fourteen, whereas, in this country, they can leave at a much younger age; and that in many parts of Germany, children leaving at fourteen are obliged to attend night schools (*Fortbildung Schulen*) for at least two years, to carry on and improve their early education.

So intimately does the problem of technical education depend upon the general education of the people, that the one question cannot be considered apart from the other. And for this reason, we were in no position twenty years ago to establish technical schools and colleges as is now being done, not only in London, but also, and to a great extent, in the provincial towns. Now, fortunately, owing to the excellent provisions of the Act of 1870, our young artisans are able to take advantage of practical scientific instruction, which they could not have done some time ago; and, consequently, the demand that is being everywhere raised for technical education is full of meaning, and must needs be satisfied. Useful, and, indeed, indispensable as is the practical training which a lad obtains in the mechanic's shop, in the builder's yard, in the weaver's shed, and in the manufacturer's works, he feels that in all these cases he is left much to himself, and that he needs the help of some one to explain the meaning of the process he fails to understand. Among the eager faces and busy hands he sees around him, each bent on doing as quickly as possible, without loss of a moment's time, which, under the system of piece-work, means money, the task assigned to him, he can find none to guide him in his difficulties and perplexities, and he is compelled to pick up as best he can, by imitation and by catching here and there a word of explanation from his seniors, a knowledge of his trade.

But let us pause for a moment to inquire why this additional and special training is needed, and why technical classes and technical schools have been established of late years throughout Europe and America, which did not exist, and were probably not required, fifty years ago.

Not now for the first time are roads made, palaces erected, beautiful garments woven, stuff dyed, pottery and painted glass manufactured. Why is it that all these things were done in former times when people were more ignorant than they are now, without technical schools or societies for the advancement of technical education? The answer is, that the conditions of production have of late years been changed; that articles which in former times were produced singly are now produced in large numbers; that the demand for what would formerly have been regarded as articles of luxury has greatly increased; and that this change in the conditions of production has radically altered the character of the training which producers of every kind require to receive. There can be no doubt that to the invention of the steam engine is due this great revolution that has been made in the processes of production, and to the same cause is due the change that is needed in the education of those who are engaged in productive industry. The break-down of the old apprenticeship system is the result of the substitution of machinery for hand labour, and as every one knows, the use of machinery on a large scale is due to the steam engine. Technical training really means art training, and in former days nearly every artisan was an artist, and the art he learnt was the trade he practised. The master was the technical teacher who taught his apprentices their trade. From him they received real and valuable instruction. To learn to saw, or to plane, to file or to turn, to spin or to weave, to dye or to print, is to learn an art; and the relations between the apprentices and master were those of the pupil to his teacher. Where the trade to be learnt was one involving fine art, the master taught his pupil to draw and to paint, to model in clay or wax, and the pupil seeing his teacher work, caught his inspiration and imitated him, and sometimes improved upon him. Objects were not then produced by thousands all of the same pattern, but each production was the result of individual thought and labour, and bore the impress of the mind and hand that conceived and fashioned it. In the region of fine art choice works are happily still produced by the same processes as in olden times, and the master artist trains up around him his disciples. But in ordinary trades the relations between the master and his apprentice are altogether changed. The master is now grown into the capitalist, and the apprentice is an uninstructed lad whose position is often nothing more than that of an ordinary servant. The steam engine has effected a complete revolution in the conditions of production. Instead of one or two persons being engaged in making the whole of any one thing, hundreds of hands are often employed in its production, each occupied with some minute portion of it, and knowing nothing of the mode of producing other parts; and thousands of articles are fabricated where one was formerly produced. Large factories have taken the place of the artisan's workshop; and whilst manipulative skill and precision count for much, these qualities may generally be acquired by constant practice, and are of less value than the intelligence and scientific knowledge which can invent a labour-saving machine, or devise the means of quickening the speed at which a piece of machinery can be made to run.

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VEGETABLE COMMERCIAL PRODUCTS.—I.

INTRODUCTION.

A PLANT is only earth and air, transmuted into those *nutrient* principles which form the food of animals. Plants form the basis of organised life. In the great laboratory of Nature they are employed in supplying the atmosphere with oxygen, and in removing its carbonic acid. No true naturalist will speak of any portion of the vegetable world as useless weeds.

But there are some plants which are especially useful to man, as sources of food, clothing, and medicine; and others are very valuable, as furnishing building materials, barks, gums, resins, balsams, dyes, oils, and perfumes. These plants are found in different countries and climates, to which, by a wise arrangement of Providence, they have been restricted. It is natural and useful to inquire, "From what countries are they brought? What quantity of them is annually imported? What are the economic uses made of their products?" Obviously, the pursuit of such inquiries must open a wide and instructive field of research.

Numerous as are the vegetable products, hitherto discovered, capable of utilisation, they are few when compared with the inexhaustible wealth of Nature. Not a year but adds in this respect something to our knowledge. When public attention shall be fully directed to this subject, an immense harvest will be reaped. Our limits will only admit of the discussion of the most valuable of them. They may be subdivided into two groups—1. Food Plants; 2. Industrial and Medicinal Plants.

1. RICE (ORYZA SATIVA). 2. MAIZE (ZEA MAYS).

FOOD PLANTS.

I. FARINACEOUS PLANTS.

The grasses (natural order, *Graminaceæ*) constitute one of the largest and most widely distributed of the natural orders of plants appearing in temperate climates in numbers so vast that they form the principal mass of the verdure which covers the landscape. The grasses of tropical climates are generally much loftier than those of the temperate zones, less gregarious, and more tufted. We give the first consideration to the Cerealia, or corn plants, the caryopsis or grain of which contains an abundant farinaceous albumen, capable of great improvement in quantity and quality. The Cerealia have been cultivated from the remotest antiquity, and were thought by the ancients to be the gift of the goddess Ceres. Their native country is unknown, and they have been so changed by cultivation, that we are ignorant, except in one or two plants, of the wild stock from which they are lineally descended. The Cerealia of temperate climates include the European cultivated grasses, wheat, oats, barley, and rye; maize and rice are the chief cereals of the tropics.

(a.) The Cerealia of Temperate Climates.

WHEAT (*Triticum vulgare*, Linnæus).—Wheat is the chief grain of temperate and sub-temperate climates. Its geographical range extends from 30° to 60° N. lat., and 30° to 40° S. lat., in the Eastern continent and Australia. Along the Atlantic portions of the Western continent the wheat region embraces the tract lying between 30° and 50° N. lat. In the tropics, wheat is cultivated only in mountainous districts, where the land is sufficiently elevated to be of the proper temperature. It is estimated that in Great Britain 2,300,000 acres are annually covered with this grain.

Wheat is imported into the United Kingdom chiefly from Europe and America. We get red and white wheat from Prussia and Austria, Spanish wheat from Bilbao, and Saxanka wheat from St. Petersburg. We also import largely from the United States, Turkey, and Egypt. The finest kind of European wheat is from Dantzic, the grain being large, white, and very thin-skinned. Nearly fifty million cwt. of wheat are imported annually, the largest amounts being received from the southern parts of Russia, Prussia, and the United States.

Wheat was formerly sown broadcast—that is, thrown from the hand of the sower over soil previously prepared by the plough. This is the most ancient mode. In modern times the plan of drilling or dibbling has been adopted—that is, depositing the seed in holes, formed in straight furrows at regular intervals.

When wheat is crushed between the stones of the mill, it is separated into two parts, the bran and the flour. The bran is the outside harder part or coating of the grain, which, intermingled with the flour, darkens its colour, and is generally sifted or bolted out to a greater or less extent. Bran is used for fattening the stock on the farm, and is of some commercial value in tanning, calico printing, for filling dolls, cushions, etc. The finest kind of bran is called middlings. Pollard is a coarse product of wheat from the mill, but finer than bran.

The whole meal, or the mixture of flour and bran obtained by simply grinding the grain, is as nutritious as the grain itself; and as bran is an alimentary substance, and equal to one-fourth the weight of the whole grain, by its separation much waste of wholesome food is caused. The great importance attached to bread perfectly white is a prejudice. Brown bread, made from the whole meal, should be adopted not merely on a principle of economy, but as containing the most nutriment.

Flour is largely imported from California and other parts of the United States, and the supply from all sources increases to a considerable extent every year.

OATS (*Avena sativa*, L.).—The oat is the hardiest of all the cereal plants, and one of the most elegant of grasses. It can be cultivated in countries where wheat and barley will not grow. Its adaptability to climate is so great that it is cultivated in Bengal as low as 25° N. lat., but it refuses to yield profitable crops as we approach the equator. The oat is cultivated in England, principally in the north and north-eastern counties, and in most parts of Wales and Scotland. It grows luxuriantly in Australia, in Northern and Central Asia, in South America, and over the whole of the cultivated districts of North America.

The meal of this grain is remarkable for its richness in gluten, and for containing more fatty matter than any other of the cereals. To these two circumstances it owes its nutritious and wholesome character. It is therefore very suitable, and much in use, as an article of diet for invalids. The variety called the potato-oat is a great favourite in Scotland, and is

almost the only kind now cultivated there. Oatmeal forms a very considerable portion of the daily food of the Scotch, and oat-cakes are much eaten in the northern counties of England.

We export no oats, as our domestic consumption is equal to the amount grown. The crop of this grain annually raised in the United Kingdom is considerably larger than that of wheat.

The use of the oat is very ancient. It is not mentioned in the Bible, but it is alluded to by the Greek and Roman writers, Dioscorides and Pliny. Caligula is said to have fed his horses with gilded oats; but this report was probably an allusion to the colour of the grain. Nearly fourteen million cwt. of oats are imported into the United Kingdom yearly, the greatest quantities coming from Russia and America.

BARLEY (*Hordeum distichon*, L.).—This grain is one of the staple crops of Northern Europe and Asia, growing as far north of the equator as 70°, and as far south of it as 42°, in favourable seasons and situations. In the New World its growth is chiefly confined to Mexico, the middle, western, and northern States, and Canada. In Asia, it is cultivated in the Himalayas and Thibet, replacing wheat in many districts, and producing admirable flour.

Barley is chiefly used for malting and distilling purposes, in making beer and spirits. When the outer coat of this grain is removed, it is called pearl barley, and in this form it is valuable for thickening broths and soups. Barley-water is a mucilaginous drink for invalids, made by boiling pearl barley.

About 10,000,000 quarters of barley are grown annually in the United Kingdom, and our yearly imports amount to nearly fourteen millions of hundredweights.

The greatest quantities are received from Denmark, Prussia, France, and Turkey proper.

Barley is a very ancient article of human food. It is mentioned in the Bible in the book of Exodus. It has been cultivated in Egypt and Syria for more than 3,000 years. Pliny calls barley the most ancient food of man. It requires very little dressing when sent to the mill, having no husk, and consequently no bran.

RYE (*Secale cereale*, L.).—This is a highly nutritious grain, but not much raised in this country, except as green fodder for cattle. In Bohemia and most parts of Germany, however, rye forms the principal crop. It is also much cultivated in the north of Europe, and in Flanders, where, mixed with wheat, and sometimes with barley, it forms a leading article of subsistence. The peasantry of Sweden live very generally on rye-cakes, baking them only twice a year; they are, therefore, the greater part of the time as hard as a board. Geographically, the diffusion of rye and barley is pretty much the same, as these plants generally grow in similar soils and situations.

Rye-straw is useless as fodder for cattle, but forms excellent thatching material, and a superior article for stuffing horse-collars, so that saddlers will usually pay a good price for it. The annual imports are considerable.

Rye is much infested by a very poisonous fungus. When attacked in this manner, it is called in England "horned rye," and in France *ergot*, from a fancied resemblance to a cock's spur. The poisonous influence of this fungus extends not only to human beings, but insects settling on it are killed, and swine, poultry, and other animals, die miserably in strong convulsions, and with mortifying ulcers. Ergot of rye is, however, in the hands of a skilful physician, useful as a remedial agent.

The principal granaries of Europe are Hungary, Russia, Moldavia, and Wallachia; and the chief ports for the exportation of grain, Archangel, St. Petersburg, Riga, Königsberg, Dantzic, Stettin, Rostock, Kiel, and Hamburg, in the north, and Taganrog, Kertch, Odessa, and Trieste, in the south. Large flour mills have been erected at Mayence on the Rhine, which is now a very important place for this branch of commerce, and at other suitable spots.

(*b*.) *The Cerealia of Warm Climates.*

RICE (*Oryza sativa*, L.).—This useful grass is a native of the East Indies, whence it has spread to all the warm parts of Asia, Africa, and America. It is a marsh plant, and grows very much like the oat, the grain hanging gracefully from the very thin, hair-like pedicles, forming a loose panicle. Rice is cultivated throughout the torrid zone, wherever there is a plentiful supply of water. Under favourable circumstances it matures on the Eastern continent as high as 45° N. latitude, and as low as 38° S. latitude. Its cultivation is principally confined to India, China, Japan, Ceylon, Italy, Madagascar, South Carolina, and Central America.

The rice from the Southern States of America is decidedly the best, being much sweeter, larger, and better coloured than that from Asia, where its cultivation is not so well managed. It is necessary to except Bengal rice, which now nearly equals that growing in the Carolinas. South Carolina produces the best American rice, and Patna the best East Indian variety. Excellent rice is also grown in the Spanish provinces of Andalusia, Valencia, and Catalonia, as well as in the marshes of Upper Italy, especially Lombardy and Venice, and in the plains of Milan, Mantua, Verona, Parma, and Modena, along the river Po.

The importations of rice amount annually to some eight millions of hundredweights. Most of our rice comes from the British and Dutch East Indies, the Carolinas, Brazil, and Egypt.

The Carolinas and Louisiana now produce annually over one million cwt. of rice, of which a large proportion is exported *viâ* Charleston and New Orleans; the Brazilian rice comes into commerce from Rio Janeiro, and the Egyptian from the Delta of the Nile, *viâ* Damietta and Rosetta.

Immense quantities of rice are consumed in England in the form of puddings and confectionery. The straw is plaited for bonnets. Rice-paper is not manufactured from this grain, but is the pith of a shrub called by the Chinese "taccada," and by botanists *Aralia papyrifera*, L. The pith, carefully removed from the stem of this plant, is first cut spirally with a sharp knife, then unrolled, spread out, and pressed flat. This paper is much used by the Chinese for water-colour paintings of insects and flowers.

Rice, although regarded by us more as a cheap luxury than a necessary article of food, forms the chief subsistence of the Hindoos, Chinese, Japanese, and other Eastern nations. The Burmese and Siamese are the greatest consumers of this grain. A Malay labourer requires 56 pounds monthly; but a Burmese or Siamese 64 pounds. The people of South Carolina do not consume much rice themselves; they raise it principally to supply the foreign demand, the swamps of that State—both those which are occasioned by the periodical visits of the tides, and those which are caused by the inland flooding of the rivers—being well suited to its production. The mountain-rices of India are grown without irrigation, at elevations of 3,000 to 6,000 feet above the level of the sea; the dampness of the summer months compensating for the want of artificial moisture.

Rice which comes to us in the husk is called by its Indian name "paddy." Before it can be used for food this husk must be removed; this is done in India amongst the poorer people by rubbing the grain between flat stones, and winnowing or blowing the husks away. Paddy is now imported into the United Kingdom in larger quantities than it used to be, though preference is still given to rice in its shelled state. In 1868 45,404 qrs. of rice in husk were imported to 4,735,997 cwt. of shelled rice; while in 1876 the relative proportions were only 320 qrs. of the former to 6,469,181 cwt. of the latter. In 1886 the total amount of rice imported was 6,557,213 cwt., valued at £2,451,572.

The cultivation of rice undoubtedly dates from the oldest period of which we have any historical record. "Cast thy bread upon the waters, for thou shalt find it after many days" (Eccles. xi. 1), evidently applies to rice, which in Egypt is always sown whilst the waters of the Nile still cover the land, the retreating floods leaving a rich deposit of thick alluvial silt, in which the rice vegetates luxuriantly. A spirituous liquor (*arrack*) is distilled from rice.

MAIZE, OR INDIAN CORN (*Zea Mays*, L.).—This plant has a strong reedy-jointed stem, as thick as a broom-handle, with large alternate leaves springing from each joint. In favourable situations this stem attains a height of from seven to ten feet; it terminates in a large compound panicle of male flowers called the *tassel*. The female flowers are situated below the male, and spring from the sides of the stem. They consist of ten or more rows of grains or caryopses, situated on the surface of a thick cylindrical pithy axis or stem called the *cob*, from eight to ten inches in length. From each of these grains proceeds a long hairy filament, the whole cob being enveloped by several layers of thin leaves, forming the husk or wrapper. The filaments of the individual grains hang together in a thick cluster out of the husk, and are called the *silk*. The filaments receive the pollen or fertilising matter from the anthers of the *tassel*;

a fact easily proved by cutting off the tassel, when the ears prove abortive. After fertilisation, both tassel and silk dry up. This plant, when grown up to some height, usually sends out several suckers from the lower joints of its stem, which help to maintain its upright position, acting as props or buttresses.

Maize may be raised on the American continent as far to the north and south of the equator as the 40th parallels of latitude, whilst in Europe its geographical range on either side of the equator extends even to 50° and 52°.

Naturalists are at no loss to determine the native country of maize, which is undoubtedly America, as the Indians throughout the continent were engaged in its cultivation when the New World was first discovered. It now forms the staple grain crop of the United States and Mexico. Since the discovery of America, maize has been introduced into the Old World, and is now grown abundantly in Hungary, Transylvania, Moldavia, and Wallachia. From these countries large quantities are annually sent down the Danube, *viâ* the Wallachian port and fortress of Galatz, into the Mediterranean as far as Malta and Trieste. Maize is also largely grown in the countries around the Mediterranean, and in Southern Germany. It is raised in India, the East Indies, and in Australia; in a word, in all those regions of the tropical and temperate zones where the white man has established himself.

Like the other cereals, maize may be reduced to meal, the coat of the grain or bran remaining mixed with the flour. Owing to its deficiency in gluten it is not much used for making bread. In the United States, however, it is made into cakes, and eaten under the name of "corn bread." In this country it is not regarded with much favour as human food, although it is both sweet and nutritious. We import it largely from America, principally for feeding and fattening cattle. In the preparation called *hominy*, the grain is first soaked, and then exposed to a dry heat, which causes the bran or outer coat of the grain to crack and peel off, when it is easily separated. *Pop-corn* is another American preparation of maize made by slightly baking the unripe grains. The corn cobs form a very cheap and useful fuel.

GUINEA CORN, DURRA, or TURKISH MILLET (*Sorghum vulgare*, Pers.).—"A roundish grain, in shape not unlike maize, but not of greater bulk than a small grain of wheat; its colour is a yellowish-white. It is borne in loose tufts or panicles; the stalks are about eighteen inches to two feet in height, and when dry are very rigid; in this state they are much used in the manufacture of carpet-brooms and whisks. The grain itself is chiefly used in this country for feeding poultry; it is, however, strongly suspected that wheaten flour is not unfrequently adulterated with it, but this can only occasionally take place, as the importation of *durra* is very irregular. It is much used as food for the black population in the West Indies, whence it has been called *negro* corn; they make of it cakes about an inch thick, which are white, and tolerably palatable. It is also used by the poorer peasants of Italy. We receive it chiefly from Northern Africa; it is, however, cultivated largely in the United States, West and East Indies, and in Southern Europe. India is its native country." (Archer's "Economic Botany," p. 8.)

AGRICULTURAL DRAINAGE AND IRRIGATION.—I.

By J. WRIGHTSON, Professor of Agriculture, Royal School of Mines.

INTRODUCTION—DEFINITIONS OF DRAINAGE AND IRRIGATION —EARLY HISTORY OF THE SCIENCE.

AGRICULTURAL drainage may be defined as the art of freeing land from superfluous water. In its more restricted sense it has reference to the improvement of land already under cultivation; in a more extended signification it includes the reclamation of land from the sea and the drainage of lakes and marshes. Viewed in connection with the natural drainage of the country by means of rivers, artificial drainage becomes of high importance as the art of improving natural outfalls; and when used for this purpose the term *trunk* drainage is applied, in contradistinction to *underground* drainage, by which is meant the more localised use of the art in draining wet soils. Although to the landowner or occupier the drainage of land surcharged with water by means of pipes may appear the more important, yet the first place must be given to trunk drainage, since without a perfect river economy much of what is now available land would be a mere swamp. Rivers may, indeed, from the drainer's point of view, be looked upon as gigantic "main drains," into which smaller streams, brooks, brooklets, and ditches, empty themselves. The series thus sketched out is rendered complete by the underground pipe drains laid in every furrow. The whole system may, indeed, be compared to a tree, the smallest twigs of which are represented by the furrow drains: just as the sprigs gradually unite into larger twigs, branches, and boughs in passing to the trunk, so in the case of land drainage do we find drains discharging into water-courses, these again into brooks and streams, which finally add to the bulk of some important river. Looking at drainage from this extended view, it at once assumes a national importance. Not only is it a means of enriching landlords and farmers, or giving an increased supply of food to the population, but it vitally affects the whole question of the water supply of the country. There is also the sanitary aspect of the drainage question, which adds to its interest and importance. Of late years much attention has been given to urban drainage, and through the value of sewage as a manure there is a close connection between this section of the subject and agriculture, insomuch that the sewage question is keenly watched and discussed by agriculturists. The climate of large districts of the country is altered and improved by the drainer's art, and instances are not wanting of certain diseases having disappeared from localities where drainage works have been extensively carried out. Hence, from an agricultural, national, and sanitary point of view, drainage is a subject of vast importance, and well deserves our close consideration.

Irrigation may be spoken of as the art of carrying water on to land in order to increase its fertility. This art has been practised from the earliest historical times in all civilised countries. Water-meadows have been established in this country for hundreds of years, but of late public attention has been aroused to the importance of still further extending the area of land thus treated. Although drainage and irrigation appear at first sight to aim at two opposite objects—the first to take water from the land, and the second to cause water to flow into it—yet they must not be looked upon as antagonistic. It may, indeed, be readily shown that, while draining frees land from superfluous moisture, it is the means of causing a larger body of water than formerly to pass through any given section of the soil. The same rainfall descends upon the drained as upon the undrained field, but owing to the arrangement of underground channels there is in the former case no puddling of the surface, no trickling *over* the land into contiguous ditches, evaporation is checked, and the land is dry because the water has *quickly passed through it*. Drainage, therefore, is a means for altering the condition of water in the soil, rather than of depriving the soil of so valuable an element of fertility. By it a stagnant condition is changed into a state of movement, and the full advantages of the rain are realised. Without it the land is waterlogged, and showers which ought to find their way down to the roots of plants soak the surface and feed the neighbouring gutters. The benefit of irrigation may likewise be traced to the constant change of the water as it passes over the surface of the meadow, giving up its riches to the herbage over which it flows. Thus drainage and irrigation may be shown to have much in common, and the idea of their being opposed to each other may be dispelled. Nay, further, as a preparatory step in the formation of water-meadows, it is often considered advisable to under-drain the field, thus showing that the two operations, so far from neutralising, may assist each other in improving the same land.

In considering such a subject as agricultural drainage and irrigation, we shall postpone the treatment of the latter for the present. Drainage may best be viewed, first, from a theoretical, and, secondly, from a practical point of view. After a few remarks on the history of the art, we shall proceed to the study of the *theory* of drainage, which comprises the reasons of its efficacy, and the study of the action of drains in soils of varying character. To thoroughly understand this part of our subject, considerable knowledge of Physics, Chemistry, and Geology is needed, all these sciences bearing directly upon it.

The practice of drainage will include a description of the various systems in vogue, a consideration of the materials fitted

for underground channels, the mode of carrying on the work, the practical good effects which may be expected to follow the operation, and the cost.

In treating of the history of drainage we shall be brief. Those who wish to study this subject fully will find abundant information, of a somewhat prosy character, in "The History of Embanking and Draining divers Fens and Marshes, both in Foreign Parts and in this Kingdom," by William Dugdale, Esq., Norroy King-at-Arms. In this work the earliest accounts of drainage, from the draining, embankments, and outfalls used in the economy of Egyptian agriculture down to the Christian era, are given; and the author cites the names of Mysis, Sesostris, Sabacon, Darius, Amasis, Alexander, the Ptolemies, Cleopatra, Cæsar Augustus, etc., as among the patrons of this useful art. To us it is more interesting to learn that the Belgic drainage works were commenced about the year 863 A.D., by Baldwin I., son-in-law of the Emperor Charles the Bold, who undertook the work of reclamation in the neighbourhood of Bruges. We also find that a marsh common law existed as early as 796 A.D. in this country, in which powers for levying rates were conferred. In the reign of Henry III. Henry de Batho framed ordinances which settled the laws and customs of Romney Marsh on the occasion of a threatened irruption of the sea through the sea-wall. Such facts sufficiently demonstrate the antiquity of drainage and reclamation on a large scale. It is hardly necessary to trace the history of the gradual change of the fen lands of the eastern counties from the home of fish and wild fowl to their present high value as corn-growing districts. The work has been accomplished by the individual energy of private individuals, by Dutch settlers, and by the powerful house of Bedford. In tracing the history of drainage we find that, although the art was understood and practised even in the most ancient times, the subject for improvement was always submerged or marshy land. If we seek for the origin of modern ideas upon drainage we shall find little mention made of the drainage of land already under cultivation, as a further improvement, until comparatively recent times. This is well exemplified by the following quotation from the late Thomas Gisborne's excellent essay on drainage, which first appeared as a contribution to the *Quarterly Review*, and was afterwards revised and published with several other essays on agricultural subjects. After stating that the first phase of the controversy between agriculture and water might rather be described as the recovery of land than its improvement, he says: "Two other cases remain in which water appears as an opponent of agriculture. The first is that in which rain, falling on pervious lands, filters through them and reappears in the shape of springs on the surface of lower lands not equally pervious, much to their injury. The second is the case of lands which, from closeness of texture, are not able to pass down the rain which falls upon them. The combat with these two cases marks two distinct eras in the history and progress of drainage."

We must view the adoption of covered drains as an improvement upon the more ancient and simple open ditch. Both plans are, however, old, and both were used by the Romans, as appears from the writings of Cato, Varro, Columella, Pliny, and Palladius.

The energy of the Romans was, however, principally directed against soils wet from springs, or the filtration of water from a higher level, and they do not appear to have attempted the improvement of soils of a more tenacious character, wet from their own inherent imperviousness.

In tracing the history of English drainage down to the present time, it is striking to note how completely the drainage of cultivated land is a modern notion. Fen lands and marshes were early reclaimed, and from time to time a note of warning was sounded, urging the importance of a more close attention to this means of utilising waste lands. Mr. Fitzherbert, who wrote on agricultural topics in 1534, says, "There is none other remedy for marrys ground but first to drain the water clean away," and this has to be accomplished by means of open ditches, having an outfall into larger or main ditches. "And," says he, "if this manner of ditching will not make the marsh ground dry, then must you make a slough (drain or hollow ditch) underneath the earth; and if that will not serve, then keep out your cattle for fear of drowning."

The earliest notice, says Mr. Gisborne, that we have of English draining is contained in a broadside in Vol. IV. of the "Collection of Proclamations, etc.," once belonging to James II., and now in the library of the Society of Antiquaries, London. "Herein," says the writer, who dates from Paine's End, November 16, 1583, "is taught, even for the capacity of the meanest, how to drain moores and all other wet grounds or bogges, and lay them dry for ever." It is also directed that the drains should be shallow, arranged in a herring-bone pattern, and filled with stones.

Captain Walter Blythe published his "Improver Improved" in 1640, and Captain Andrew Yarranton wrote, in 1677, "England's Improvement by Sea and Land." Both were authorities on draining, and the former has been frequently quoted to show how little the last two centuries have done to improve the drainer's art. Blythe describes in somewhat quaint language the essentials to success in draining wet soils, when he says, "And for thy drayning trench it must be made so deepe, it go to the bottome of the cold spewing moyst water that feeds the flag and rush . . . . and a yard or four feet if ever thou wilt drain to purpose." It would occupy too much space to quote more from a work interesting not only from its merit as an agricultural treatise, but also from its quaintness. In it we are recommended to use fagots of "willow, alder, elm, or thorns, and lay in the bottom of thy works, or take great pebble stones, or flint stones, and so fill up the bottom of thy trench about fifteen inches high, and then, having covered it all over with earth, and made it even as thy other ground, wait," says the gallant old Cromwellian, "and expect a wonderfull effect through the blessing of God."

In 1727, R. Bradley, Professor of Botany in the University of Cambridge, gives us, in his "Complete Body of Husbandry," some valuable information upon the then state of knowledge upon the question of land drainage. Good practical directions are given for open ditching and "hollow ditching" (covered drains); but his attention appears to have been directed to the drainage of land "which lies wet and is a kind of lake, so that one cannot tread upon it but the water feels like a quag under one's feet." Then follow directions, which resemble those given by Captain Blythe eighty years previously, but whose valuable work appears to have at that time sunk into obscurity. "This improvement (drainage) is chiefly practised in Essex. I have seen it at Navestock, on the forest, at an estate belonging to Aaron Harrington, Esquire, and it is lately brought from that part of the county to the north of Essex, about Wicken-Benant, and near Sir Kane James's; and I doubt not but will be generally used upon all the squally, wet grounds in England, when it comes to be known, for it is but a late invention." This author also describes the use of windmills in raising water from a dead level, as commonly seen in Lincolnshire and the fen county; the Persian wheel and the syphon, or, as it is termed, the "crane," are also described and figured as an appliance for lifting water over an embankment; "but," adds the conscientious author, "I cannot take this thought to myself no more than I have done any others that have been communicated to me. I received it from Mr. Harding, a very ingenious founder and master of mechanicks, near Cupid's Stair, over against Summerset House, London" (even professors at Cambridge were not particular in their spelling one hundred and sixty years since). The next great luminary in the history of the art of agricultural drainage was Mr. Joseph Elkington, of Princethorpe, Warwickshire, who commenced farming in 1730. The principles upon which Elkington based his practice were not capable of extensive application, but under certain conditions of soil and subsoil they have been carried out with excellent results. We shall again have occasion to refer to this period when speaking of the practice of drainage. From 1797, the year in which Elkington's system was given to the world by John Johnston, surveyor, in the form of a work, illustrated with numerous diagrams, down to 1823, little attention was bestowed on the subject of land drainage. It was at this time that the late Mr. Smith, of Deanstone, introduced the subject of "thorough draining" to the British public, and gave an impetus to the good work which has sent it rolling onwards ever since. Finally, the use of the cylindrical draining pipe, both by cheapening the material of the underground channel, and reducing the trench to the narrowest possible width, brings us down to the present day, when draining is universally looked upon as the foundation upon which all other agricultural improvements must be based.

FORTIFICATION.—I.

BY AN OFFICER OF THE ROYAL ENGINEERS.

PRELIMINARY REMARKS—DEFINITION OF SCALES—DEFINITION OF TERMS USED IN GEOMETRICAL DRAWING—SLOPES: HOW EXPRESSED—DEFINITION OF THE TERM FORTIFICATION—CONDITIONS THAT, IF POSSIBLE, EVERY FORTIFICATION SHOULD FULFIL—ERRONEOUS IMPRESSIONS HELD WITH REGARD TO THE USES OF FORTIFICATION—SUBJECT DIVIDED INTO TWO BRANCHES—FIELD FORTIFICATION—PERMANENT FORTIFICATION—DEFINITION OF A PARAPET—MATERIALS OF WHICH PARAPETS ARE CONSTRUCTED.

Preliminary Remarks.—The science of Fortification is one so intimately connected with other branches of military art, that it can hardly be rendered interesting or even intelligible to a student who has not previously acquired a certain amount of general military knowledge, sufficient to enable him to realise fully the main principles and conditions under which modern warfare is carried on.

Unless the reader clearly understands the differences existing between the uses and powers of the three great combatant branches of every army—viz., infantry, cavalry, and artillery—it would be useless to attempt to describe to him the defensive arrangements best suited to either of these arms. A certain knowledge of military matters will, therefore, be assumed in these papers, but when technical expressions occur they will be explained.

Most of the operations of fortification are those of practical building or construction, and it is often necessary to express, on the flat surface of the paper, solids of very varied forms; consequently the methods of doing this by means of plans, sections, etc., must be learnt before any real progress can be made.

These methods form the subject of a separate study, termed Geometrical Drawing, and will therefore only be so far explained as may be necessary to enable a reader to understand the diagrams attached to these papers.

In order that the meaning of a drawing of this description may be clearly understood, it is necessary that it should convey not only an idea of the shape and appearance, but also of the actual size of the object it represents.

Definition of Scales.—It is evident that it will often be impossible to make drawings as large as the objects they represent, and it becomes necessary, therefore, that in every important drawing a certain fixed proportion should exist between it and the object represented. This proportion is termed the *scale* of that drawing, and is usually expressed by means of a fraction written on the drawing itself—thus, scale $\frac{1}{120}$, or scale $\frac{1}{480}$, would denote that the objects represented were 120 or 480 times as large as the respective drawings.

The shapes of solids are usually denoted on paper by means of plans, profiles, and elevations.

Definition of Terms used in Geometrical Drawing.—The *plan* gives the length, breadth, and general direction of every part of a work, and is a representation on a horizontal plane of the various lines or edges formed by the intersection of the plane surfaces that bound the solid.

The *trace* of a work is the plan of its guiding or magistral line.

The *section* of a work is the outline of the surface that would be exposed by a plane cutting through the solid in any direction.

The *profile* is a vertical section at right angles to the trace, and shows the true heights and breadths of the object.

The *elevation* is the outline of an object projected on a vertical plane, and gives the heights and general appearance of the various parts.

Slopes: how Expressed.—The degrees of inclination, or steepness of slopes, are expressed by fractions; the slope being considered as the hypothenuse of a right-angled triangle, of which the height is represented by the numerator of the fraction, and the base by the denominator; thus, a slope of

$\frac{1}{1}$ means that the height = base.
$\frac{1}{2}$ „ „ height = $\frac{1}{2}$ base.
$\frac{2}{1}$ „ „ height = double the base.
$\frac{3}{4}$ „ „ height = $\frac{3}{4}$ of the base.

The foregoing elementary definitions being understood, we should next get a clear notion of the principles of the science before becoming involved in its details.

In all ages we find that men, prompted by the instinct of self-preservation, have availed themselves of artificial aids in war, either simply as a means of protection from the missiles of an enemy, or to enable a weaker force to neutralise the advantage that superior numbers or armaments would give to their opponents.

Definition of the term "Fortification."—The various practical operations resorted to are essentially defensive in their nature, and the science which treats of the different ways of applying them to strengthen positions held by troops is termed Fortification.

These operations present an almost infinite variety of detail, for they depend necessarily on the special objects for which they are intended, and the time and means available for their construction.

A knowledge of details is undoubtedly essential in fortification, as in every other practical science; at the same time it will be more important for the student at first to realise the fact that he is not dealing with an abstruse or complicated subject, but merely applying practical common sense to the art of defensive warfare, his object being in all cases to make such arrangements as will oblige the enemy to fight under the most disadvantageous circumstances possible.

Conditions that, if possible, every Fortification should fulfil.—To attain this object thoroughly, every work should fulfil the following conditions:—

1. To afford cover and protection from the enemy's missiles.
2. To enable the defenders to use their weapons with the greatest effect, and with the least exposure to themselves.
3. To render the advance of the assailants as difficult and slow as possible while within the effective range of the works.

These principles are often very difficult to combine, and their application to positions where the circumstances are unfavourable will require the exercise of much thought and ingenuity.

Fortification is necessarily a progressive science, ever changing in some important details as the development of the sister science of Artillery may require; hence it is that we find such a variety in the forms and appearance of the defensive works constructed at different periods and in different countries. A close study of them will show that, however unlike they may appear in some respects, the same principles may be clearly traced through all; not less, perhaps, in the New Zealand "pah" than in the mediæval castle or the modern fortress, if the weapons for which each were intended are borne in mind.

There can be no doubt that, when properly applied and these conditions fulfilled, fortification must ever be of vast assistance to the defence; it can, however, only give a passive assistance, and should not be confounded, as is so frequently the case, with the defence proper, or actual fighting power of the defenders.

Good defensive works undoubtedly enable a small force to fight a much larger one on tolerably equal terms, and, moreover, a less amount of training and organisation is necessary to enable troops to defend fortifications than would be required for manœuvring in the field.

It must, however, be remembered that fortifications without sufficient men and guns to defend them would offer no real obstacle to an enemy, and that unless the offensive powers of the defenders be considerable, they may, in spite of their defences, be defeated by a superior force.

Erroneous Impressions held with Regard to the Uses of Fortification.—Nothing is more common than to hear it argued that because a fortified position is carried by assault, therefore the fortifications were useless, ignoring the fact that if the defenders were unable to repel their assailants when assisted by artificial aid, they would not have had a chance of victory in open fight, and that the loss they have inflicted, as compared with their own, is probably far greater than it otherwise would have been.

Another favourite argument against the use of fortifications is that if they are well placed, and well constructed, the enemy will probably not attack them at all, but will endeavour to pass round, or turn them, as it is termed, and that, therefore, they are useless.

Let us examine this for a moment. It is evident in an attack on any position or territory, there must be a certain definite object in view, and that, in order to obtain this object, there must be certain parts of that position or territory which will be most essential for the assailant to get possession of. Now, if

these vital points are so strengthened by artificial means that, in spite of his superiority of force, the assailant prefers to adopt some other less advantageous scheme, to the certainty of heavy loss and possible defeat in attacking the works, it is clear that these fortifications will have materially assisted in protecting the position or territory, although they themselves were not actually attacked.

Subject divided into Two Branches.—For convenience in instruction, the subject is usually divided into two branches, termed Field and Permanent fortification, although it is by no means desirable that they should be considered as separate studies, for precisely the same principles apply to both; and in permanent fortification we merely see them combined in a complete form, whereas this can only be imperfectly attained in field fortification.

Field Fortification.—This has reference to temporary works constructed during a campaign, within a limited time, and with such unskilled labour and ordinary materials as can be obtained on the spot.

The strength of this class of works varies considerably, from the carefully constructed redoubt, in which all the requisite conditions are fulfilled, to the hasty shelter-trench, or the rough lines of felled timber that so often afforded bullet-proof protection to the troops in the battles of the late American war.

The weak point of all field works, as compared with permanent fortifications, is that, from the fact of their being constructed in a short time, the obstacle they oppose to the advance of the enemy is very much less formidable.

Permanent Fortification.—Permanent fortifications, as the name implies, are constructed of durable materials, and during times of peace, when the choice of materials is unlimited, and when everything is done that skilled labour and elaborate design can accomplish, to render the defence as perfect as possible.

They are intended to secure from immediate capture the arsenals, dockyards, and other points of vital importance in a country liable to attack.

Permanent fortifications are necessarily very costly to construct, and unless destroyed by an enemy will endure for centuries, outliving the men who built them, and the artillery, and even the objects for which they were designed. Hence it is that we so frequently find examples of fortifications that are now obsolete, and we are apt to consider that it was a great mistake ever to have built them, forgetting that they, perhaps, have been of the greatest national importance for many generations, and would be so still, had the art of war remained stationary during that period.

Definition of a Parapet.—To fulfil the conditions of intercepting the projectiles of an enemy, and of enabling the defenders to use their arms with effect, a covering mass of some material is necessary, which must have sufficient strength to resist the enemy's shot, and over or through which the defenders may fire. This mass is called the *parapet* (derived from the Italian words "para petto," *guard the breast*), and its dimensions as regards height are dependent to a great extent on the ordinary stature of men, whilst its thickness must depend on the materials of which it is formed, and the nature of projectile it is intended to resist.

This parapet is usually constructed of earth or sand, as being the material most readily obtained, and most indestructible by an enemy.

Materials of which Parapets are Constructed.—In countries where timber abounds, and where the heavy fire of artillery has not to be provided against, parapets may be constructed of logs of wood placed touching one another, so as to give good bullet-proof cover. They have the disadvantage of being liable to be burnt, and if struck by shot the splinters of the wood are dangerous. They are called "stockades."

In some cases where it is impossible to obtain sufficient earth, or where, from the small area available, it is necessary to economise space as much as possible, masonry, and even iron, may be used as materials for parapets. The time required to construct them, and their cost, prevent the employment of these latter materials for any but permanent works. They are chiefly employed in harbour and coast defences, where it frequently happens that the small islands or rocks that are most advantageously situated for the defence of the coast, are too small to admit of a sufficient number of large guns being placed on them, if they are to be surrounded by thick and massive earthen parapets.

ELECTRICAL ENGINEERING.—I.

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INTRODUCTORY.

THE science of Electrical Engineering is one which has attained its present prominent position in what may be called a phenomenally short space of time. Its growth within the Victorian era has no parallel among the kindred sciences. It would seem as if men during that time were endeavouring to make amends for the lethargy into which their forefathers had apparently fallen for something like two thousand years; for it is fully two thousand years since the two primary discoveries were made in electricity* and magnetism. The first was, that if a piece of amber was rubbed it acquired the property of attracting light bodies; the second was, that certain black stones, found at that time in Magnesia, in Asia Minor, possessed the property of attracting iron. These stones were called magnets, from the district in which they were first found. Here were two facts thoroughly recognised some five hundred years B.C., and yet it was not till fifteen hundred years later that the discovery was made that if the magnet was suspended by a thread it took up a position pointing north and south; and that it took up this position at no matter what part of the earth the experiment was made. From this peculiarity it received the name of the *lodestone*. The importance of this discovery on navigation need scarcely be pointed out.

The next great discoveries were those made by Dr. Gilbert,† in England, published at the end of the sixteenth century. He showed that the property which was supposed to be peculiar to amber, when rubbed, was common to a large number of other bodies, notably to glass, most of the precious gems, sulphur, resin, etc.; in fact, to those bodies which are now known as non-conductors. But though the effects obtained from these bodies were perfectly distinct, still they were necessarily extremely feeble. It now became important to exaggerate these effects, and this object was successfully accomplished by Otto Guericke,‡ who mounted a large sulphur ball on a spindle, which was turned by one person while another held his hands on the revolving sulphur ball. The necessary friction was thus supplied for the production of electricity, and when the machine was worked in the dark a series of sparks was given off from it. This *frictional* machine was subsequently modified and considerably improved; but the most that could be got out of it was a series of sparks more or less bright, which could be made to pass between two points or knobs, one of which was attached to the rubbing, and the other to the rubbed, surface.

All that these machines were capable of doing could, however, be done very much better by the class which succeeded them, namely, the *influence* machine. The action of this machine depended on a principle entirely distinct from that of the frictional machine; and in respect of the number, brightness, and length of the sparks which could be obtained, the influence was in every way superior to the frictional machine.

These machines undoubtedly showed an advance in the science of electricity, and it might even be said that the spark obtained from them was the original form of the electric light; but when looked at from a commercial standpoint, it must be confessed that the electrical machine, as it then existed, was nothing better than an interesting scientific plaything, highly dangerous to ordinary mortals, and not quite safe in the hands of those who best understood it. It supplied extremely feeble and intermittent electric currents forming sparks, but the supplying of a continuous current, no matter how weak, was a task utterly outside its scope; and it was the solution of this problem—how to supply a continuous current—that has made the names of Galvani and Volta so familiar to every one who has taken any interest in electricity.

While experimenting with recently-skinned frogs' legs, about the year 1785, Galvani discovered that if an iron wire which is touching the crural (leg) muscles is brought into contact with a

* From the Greek, *elektron*, amber.

† William Gilbert (*b.* 1540, *d.* 1603) was surgeon to Queen Elizabeth. In his book "De Magnete," he was the first to use the word "electric" in connection with science.

‡ Otto von Guericke of Magdeburg was born in 1602 and died in 1686.

copper wire which is touching the lumbar (loins) nerves, the frog's leg gives a convulsive movement, and that it does this every time the wires are brought into contact. Galvani knew that this convulsive movement was due to electricity, but he failed to see from what source this electricity was derived. He attributed it to electricity inherent in the frog's leg, and from this opinion he never wavered. Volta, however, fully recognising the importance of the discovery which Galvani had made, attributed the convulsive movement to its true cause, namely, electricity derived from chemical action; and this point he completely proved in the year 1800, by constructing what is known as the *Voltaic pile*. This pile consists of a series of discs of zinc and copper separated by wet cloth, and connected by two wires, one attached to each end of the series. When these wires are brought into contact a continuous current circulates through them, while a small spark is formed when the contact is broken; the zinc is dissolved, and this slow combustion of the zinc furnishes the requisite energy for the supply of the electric current. A new form of electricity, in the shape of a continuous current, was now available, and a new method of generating it, namely, chemical action. The Voltaic pile is, in fact, a true primary battery; and though it possesses nearly all the faults which a primary battery can possess, still it none the less marks an epoch in the history of electricity which cannot but be looked upon as the point from which the science began to make more rapid progress.

It was introduced into England in the same year, 1800, and so rapid was its development and improvement that four years later Humphry Davy was able to exhibit before the Royal Institution the true electric arc-light. After experimenting with numerous substances, he found that he got the brightest light when charcoal points were used. He took two charcoal rods, attached one to each end of the battery, and brought them into contact. A strong current now flowed through them, and on separating the points to the distance of about a quarter of an inch, an intensely bright light was formed between the points. This luminous space is known as the *arc*. This arc is composed of incandescent particles of carbon torn off from the points, and conducting the current across the gap. It is so hot that it can melt the diamond, while it vaporises gold and platinum. When the arc is formed in air the rods gradually wear away, the arc grows longer, until the distance between the points becomes too great, when the arc ceases. In our modern arc lamps a special mechanism is used to keep the distance between the points constant.

The electric current heats to some extent everything through which it passes. If we take a thin carbon filament, and pass a sufficiently strong current through it, it will first be raised to incandescence, and then oxidised and quickly burnt away. But if we enclose the filament in a vacuum, and perform the same experiment, the result will be different. The filament will still be raised to incandescence: but, there being no oxygen present, it will not burn away; in fact, it will last for some thousands of hours, giving a bright light during the whole time that the current is being supplied to it. This latter type is known as the *incandescent lamp*. It usually gives about sixteen- or twenty-candle power, while the arc light usually varies between five hundred and three thousand. We are thus able to obtain heat from the electric current, and, as might be supposed, the converse proposition also holds good—that is, *from heat properly applied to a suitable arrangement we can obtain electric currents*. The discovery of this fact was made by Seebeck about the year 1822. He found that, if he heated the point of contact of two dissimilar metals, and brought their other ends into contact with an instrument capable of indicating the presence of a current, a current was actually generated in the circuit. This current lasted as long as the temperature of the heated junction was kept above that of the remainder of the circuit, and its strength depended upon the difference of temperature of the two portions; its strength also depended upon the metals used. Bismuth and antimony form an admirable pair; the direction of the current through the heated junction being from bismuth to antimony. The necessary energy for the production of the current is supplied by the heat absorbed at the hot junction of the two metals, and the currents thus generated are known as *thermo-electric currents*. Much good work has been done by means of thermo-electricity, and even at the present day there are some telegraph lines being worked by means of it; but it cannot be said that the progress which has been made in it can in any way compare with that which has been effected in some of the other branches of the science. Suggestions have often appeared for the utilising of the spare heat given off from our common fire-grates, but up to the present no practical means have been devised for doing this in a satisfactory manner.

Very soon after the construction of the Voltaic pile it was discovered by Carlisle and Nicholson that if a current was passed through water it decomposed some of the water into its constituent elements, oxygen and hydrogen. These elements were given off in the form of gas from two points—where the current entered and where it left the liquid—the oxygen from the former point, and the hydrogen from the latter. On further investigation it was found that nearly all the solutions of metallic salts and acids behaved in a somewhat similar manner. This phenomenon has received the name of *electrolysis*, and the liquids which can be thus decomposed are called *electrolytes*. If a solution of sulphate of copper—blue vitriol—is subjected to electrolysis, the reaction which occurs is simple and interesting. Let us suppose that the current is being led into and out of the liquid by means of platinum plates—platinum is used for this purpose, as it is not acted upon by any acid, nor is it easily oxidised. When the current passes, the liquid is decomposed, and copper is deposited on the plate which leads the current out of the liquid. If this process is continued for a sufficiently long time, and the copper sulphate solution is not exhausted, a thick coating of pure copper will be deposited on the platinum plate. This coating of deposited copper will fit into, and fill up, the most minute inequalities which may exist on the platinum plate, and if it can be afterwards removed from it, it will be a reproduction, accurate to the most microscopic detail, of the plate on which it was deposited. If, on the other hand, it is desired not to take an impression of the plate, but simply to cover it with a coating of copper, the strength of the current is so adjusted that the rate at which the copper is deposited shall be that which experience has shown will give a uniform and firm deposit. The plates which lead the current into and out of the liquid need not necessarily be platinum. Any other substance through which electricity can flow, and which is not decomposed by the liquid, will answer quite as well, and the result will be exactly the same; so that all that is necessary, in order to obtain an electrotype from any article, or to plate it with a coating of copper, is to substitute it for the platinum plate, and subject it to the above-described process. In a similar manner gold, silver, platinum, nickel, iron, zinc, brass, etc., can all be deposited from their proper solutions, and, though each particular metal may require many special precautions to be taken, in order to insure satisfactory results, still the one leading principle just described governs the deposition of all. The electro-plating industry is necessarily the outcome of Volta's discovery, though the introduction of the dynamo-machine for the supply of large currents is fast driving the Voltaic cell out of the market for this particular purpose.

PROJECTION.—II.

PROJECTION OF DOOR—TRAP-DOOR AND FRAMING—CUBES AND PRISMS—TO PROJECT A CUBE—SHADE LINES—TO DEVELOP A CUBE.

It will be remembered that in the previous lesson the method of projecting first single lines, and then planes at various angles, was treated of. The present studies are familiar applications of the principles laid down.

Fig. 11 represents a door when the wall is parallel to the vertical plane, the door being at an angle to it. The plan should be drawn first, and the elevation projected from it.

Fig. 12 represents a trap-door and framing, the door being inclined to the horizontal plane, supported in that position by a piece of timber. In this figure the plan of the framing should be drawn first; then its elevation. To this elevation the edge of the trap-door should be added, which should then be projected on to the plan.

In Fig. 13 the entire plan rotated should be drawn first, and the projection obtained by drawing perpendiculars from the angles, and intersecting them by horizontals drawn from the corresponding points in the elevation.

*

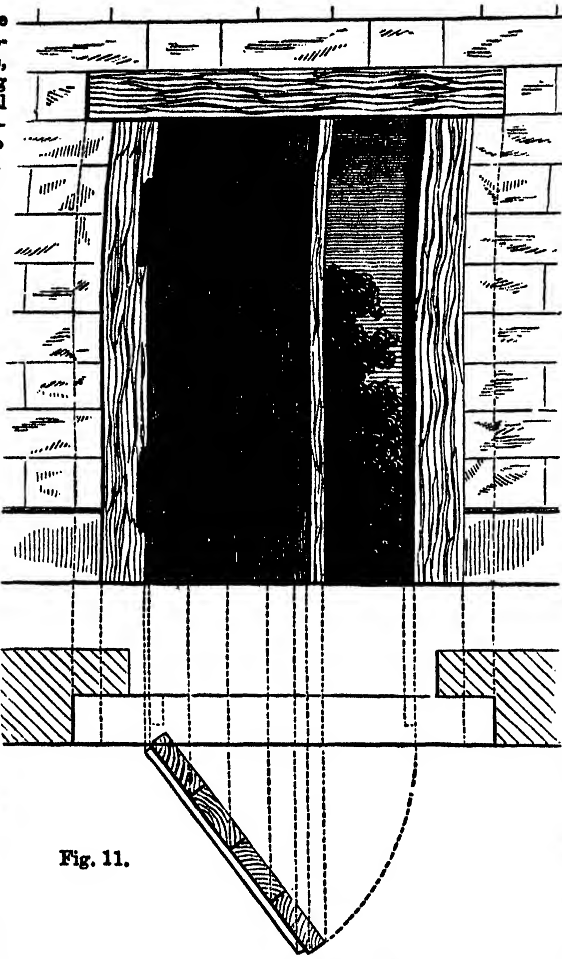


Fig. 11.

Fig. 14.—Here a plane square is placed with its surface parallel to the horizontal plane, and its edges, a, b, c, d, making angles of 45° with the vertical plane. As this plane is supposed to possess little or no thickness, its elevation, when lying flat, is merely the line $a'\,d$; the angle c, and b which lies directly above it, being marked $\overset{b}{c}$. If we now raise the square, allowing it to rest on the angle a, the extremities of the diagonals, d, c, and b, will travel through parts of circles. Thus, let it be required that the diagonal $a\,d$ shall be parallel to the vertical plane, and inclined to the horizontal at 45°. Draw a perpendicular from a to the intersecting line, and thus obtain a'. From a' draw a line at 45°, and with radius $a'\,c$ and $a'\,d$ describe arcs cutting the inclined line in $\overset{b'}{c'}$ and d'; the extremities of the diagonals are thus transferred from the horizontal to the inclined elevation.

Now the points $\overset{b}{c}$ and d, in rising higher, will also have moved towards a in the plan, in the track indicated by dotted lines; their present position is determined by dropping perpendiculars from $\overset{b'}{c'}$ and d' to cut the dotted lines; and the points being united by lines, the plan of the square in the required position will be obtained.

Let it now be required to obtain the projection of this square, when, in addition to the diagonal $a\,d$ being inclined at 45° to the horizontal, it is inclined at 60° to the vertical plane; in other words, keeping the square resting on the point a', inclined at its present angle, and rotating it. The plan then will be the same as in Fig. 14, but turned round until $a'\,d'$ is at 60° to the intersecting line; then perpendiculars raised from each of the angles, intersected by horizontals from the corresponding points in the previous elevation, will give the projection in Fig. 15.

The same plan turned so that $a\,d$ is at right angles to the intersecting line, and worked out as in the last figure, will give the projection of the square when resting on one of its angles, its plane being at 45° to both the planes of projection. It will be seen that the diagonal $c\,b$ has, in all three figures, remained parallel to the *horizontal* plane; but in Fig. 16 it will be observed to be parallel to *both* planes.

The student who has thoroughly mastered the foregoing lessons will have seen that, when he understood the projection of *single lines*, he soon comprehended the delineation of planes, since planes are but forms bounded by lines. It is hoped that the next step, the projection of solids (from the Latin solidus, *compact*), may be divested of some of its apparent difficulties, by the reflection that solids (excepting the sphere and its allied forms, no portions of which are absolute planes) are made up of planes, and that thus, when planes can be projected separately, it will be easy to work out several combined in one object. Thus a cube, or solid square, is formed of six equal squares; and as each of these sides is parallel to the opposite one, the trouble will not be much more than projecting three planes.

CUBES AND PRISMS.

When three or more planes meet at one point, as the corners of a cube, they form a *solid angle*.

A prism is a solid whose opposite ends are equal and similar plane figures, and whose sides, uniting the ends, are parallelograms.

The ends of prisms may be either triangles, squares, or polygons.

A line drawn from the centre of one end of a prism to the centre of the other is called the *axis*.

TO PROJECT A CUBE.

First Position (Fig. 17).—When standing on the horizontal plane, its axis being vertical, and its sides at 45 degrees to the vertical plane.

Let $a\,b\,c\,d$ be the plan of the cube, and e the plan of the axis. Draw perpendiculars from each of the angles of the plan, and make the height above the intersecting line equal to the side of the plan. Draw the top line, $a\,d$, which will complete the elevation, the axis being hidden by the edge, c.

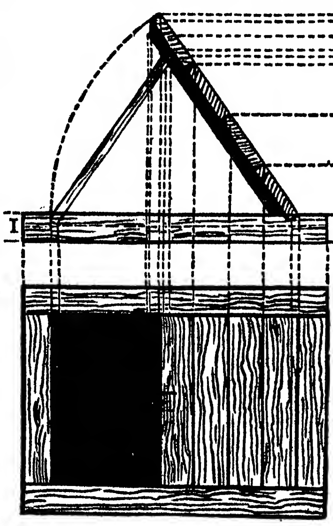


Fig. 12.

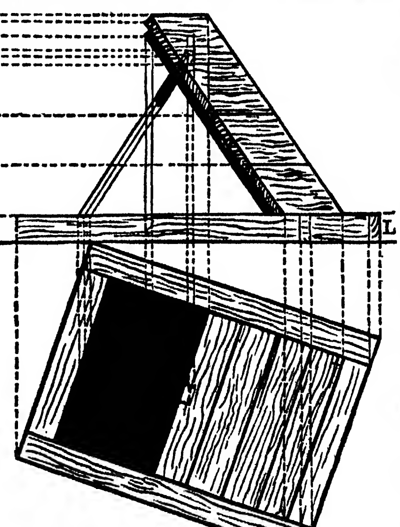


Fig. 13.

Second Position (Fig. 18).—When resting on the solid angle, *a*, its axis being inclined at 65° to the horizontal, and parallel to the vertical plane.

As the axis of a prism is *parallel* to *its edges*, it will only be necessary to place the elevation of Fig. 17 so that the edges are at 65°, then the axis will be between the edge *c c* in the front, and *b b* beyond; and as the diagonal, *a d*, which forms the intersecting line. Draw perpendiculars from the solid angles of the plan, and horizontals from the corresponding points in the elevation of Fig. 18. The intersections of these two sets of lines will give the points for the projections.

Shade Lines.—The light has been supposed to come in the direction of the parallel lines on the left of the point *a*. Thus the sides *c d* and *d b* are in shade. This is indicated by the

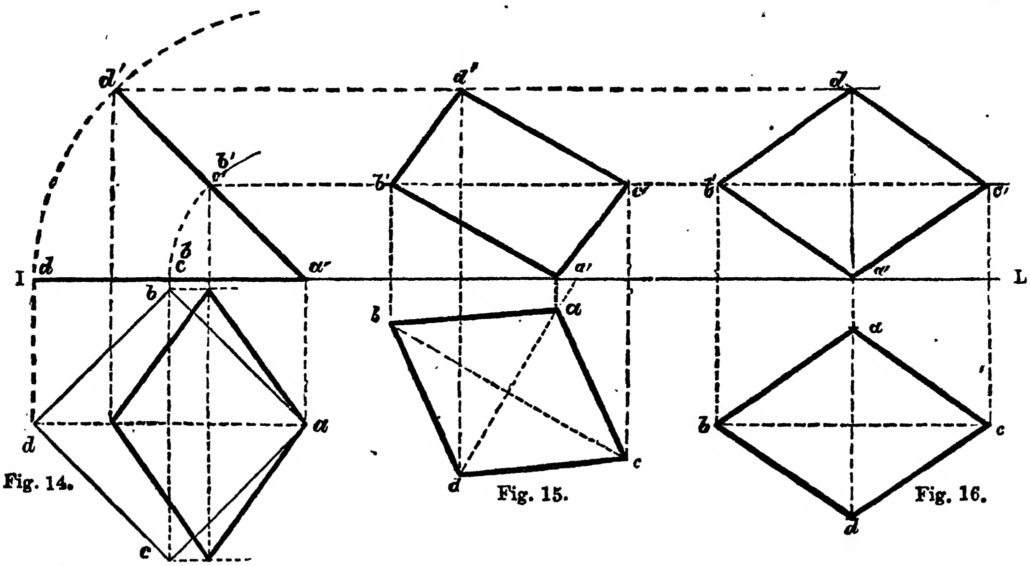


Fig. 14. Fig. 15. Fig. 16.

the breadth of the base, is at right angles (90°) to the edge, *a a*, the plane of the base will be at 25° to the horizontal plane. Perpendiculars dropped from the angles of this elevation, intersected by horizontals drawn from the corresponding points in the plan of Fig. 17, will give the plan of Fig. 18, or the view obtained by looking down on the elevation, in the direction of the arrow. The axis, *e f*, will now be seen.

lines on the plan being darker than the others, and all perpendiculars rising from them will be dark also.

Development.—The development is formed by the shapes of all the sides of an object being laid down on a flat surface, so that when folded, or connected, a given solid may be either constructed or covered. By *solid* is here meant an object that has the external appearance of solidity. Whether the body

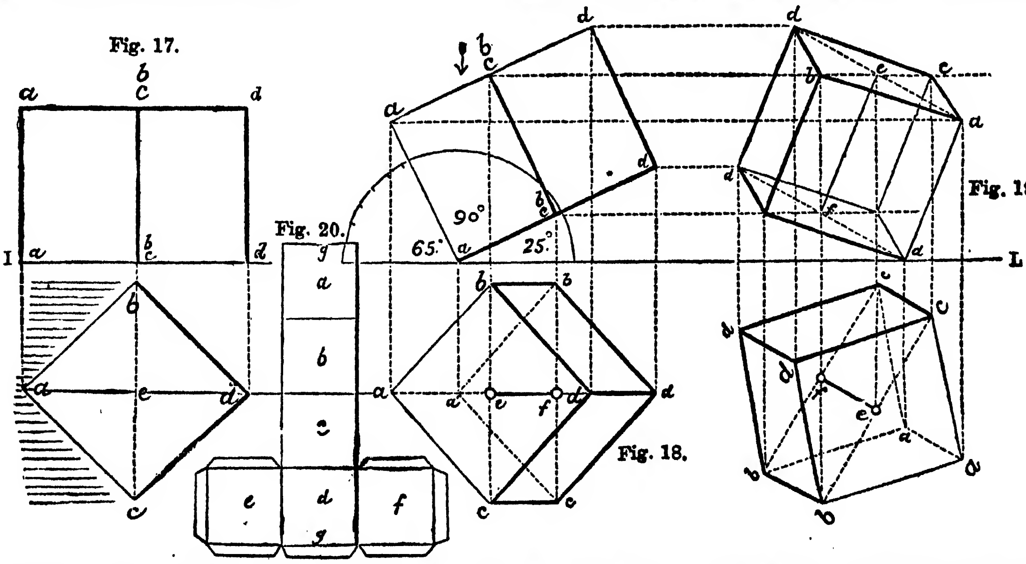


Fig. 17. Fig. 20. Fig. 18. Fig. 19.

The student is urged to letter with the utmost care until he has become accustomed to follow each point through its various changes of position. In Figs. 17, 18, 19, 20, and all subsequent projections of prisms, the points of the base, or lower end, will be marked with the same letters as those of the opposite or upper end, but in smaller characters.

Fig. 19.—When the axis of the cube is at 65° to the horizontal and 30° to the vertical plane.

Place the plan so that the line of the axis, *e f*, is at 30° to be really solid or hollow will be subsequently determined by sections or cuttings.

To Develop a Cube (Fig. 20).—A cube consists of six square sides. Let *a*, *b*, *c*, *d* be four of these, which, uniting at *g*, *g*, will form the walls, then *e* and *f* will be the top and bottom. A very useful model may be thus formed. The strips left at the edges will be found useful in fastening the sides together. If the model is made of cardboard the lines should be cut half through, and half the thickness of the strips peeled off

MINERAL COMMERCIAL PRODUCTS.—II.

IRON (*continued*).

Iron pyrites, mundie, the bisulphide of iron (FeS_2), is diffused through rocks of all ages, but the presence of sulphur makes it valueless for the production of iron. It is important, however, both directly as a source of sulphur and sulphuric acid, and indirectly in the immense number of the useful applications of this latter product. Pyrites sometimes contains gold, and it is then called *auriferous pyrites*. Wicklow, Cleveland, Bohemia, Spain, Portugal, and Norway possess very large quantities of this mineral.

Phosphates of iron are worked in Canada, and *silicates* in Switzerland.

The principal processes to which iron ores have to be subjected, in the preparation of iron and steel for manufacturing purposes, are roasting and smelting, refining and puddling, cementation and tempering, varying with the nature of the ores. The roasting process—chiefly necessary for impure ores—gets rid of combustible matter, water, and carbonic acid. The smelting, conducted in large blast furnaces, disengages the metal from the oxygen and earths of the ores, and brings it into the marketable form of cast-iron, in pigs. This is really a carbide of iron, containing a considerable proportion of carbon, with small quantities of some other substances, such as silica and potash, derived either from the ores or the fuel. It is very brittle, and suitable only for castings: and, according to its quality, it is grey iron, which is the best; mottled; and white, which is the worst. Refining, a re-melting of the metal with coke or charcoal, removes some of the carbon and silicon, and produces what is called fine metal. The puddling, which is carried on in a reverberatory furnace, disengages further quantities of these impurities, and makes the iron malleable, prepared in bars or sheets, as required. By cementation, or heating with charcoal, bar-iron is made into blistered steel. From this, by welding, shear-steel is made; and by re-melting and casting, the cheaper cast steel is obtained. Spathose pig-iron can be converted into steel without any intermediate processes. This is done in Styria and other parts of the Continent, and in Borneo. The produce is called natural steel, and is of very fine quality. Ordinary cast-iron, annealed—called "run-steel"—can sometimes be substituted for steel. The tempering of steel, to adapt it, as regards hardness and ductility, for its various purposes, is effected by the processes of re-heating and sudden cooling.

In 1886 there were imported 2,878,469 tons of iron ore, valued at £1,894,626; of pig and puddled iron, 45,195 tons, valued at £221,578; of bar, angle, bolt, and rod iron, 105,466 tons, valued at £957,057; of old broken iron and old cast iron and steel, 12,046 tons, valued at £31,873; of unwrought steel, 12,082 tons, valued at £112,342; of sewing-machines, £258,740 worth; of unenumerated iron manufactures, 3,537,652 cwt., valued at £2,200,265. For the same year (1886) the total quantities of iron exported were as follow:—Of old iron for re-manufacture, 144,860 tons; of pig and puddled iron, 1,044,552 tons; of bar (except railroad), angle, bolt, and rod, 242,947 tons; of railroad of all sorts, 739,603 tons; of hoops, sheets, and boiler plates, 307,756 tons; of tinned plates, 334,692 tons; of wire, 40,341 tons; of cast and wrought iron and all other manufactures, 353,923 tons; of unwrought steel, 166,367 tons; of manufactures of steel, or of steel and iron, 13,453 tons—making a total of 3,388,494 tons, valued at £21,817,720.

GOLD.

This noble metal is unaffected either by air or water, and is of great and almost universal use. In civilised countries it forms, as coin, the principal medium of exchange, besides being used in the form of gold-dust for a similar purpose among semi-barbarous nations; and from the richness of its colour, and its imperishable nature, it enters very largely into the composition and ornamentation of such articles of utility and luxury as require to be both durable and beautiful. For all these purposes it is peculiarly fitted by its weight (sp. gr. 19·5) and its extraordinary malleability and ductility. In virtue of these latter qualities it can be hammered out into leaves of 282,000 to an inch, and a single grain can be extended into 500 feet of wire. Its natural softness can be corrected by a slight alloy of silver or copper, and in this state it is commonly employed.

Gold is more generally diffused throughout the globe than any other metal except iron, but not in all places in sufficient abundance to render its collection or extraction profitable. It occurs mostly native, being either pure or alloyed with silver, tellurium, and other metals; and often associated with the sulphides of iron and silver.

The modes of occurrence and association of gold are as follow:—

1. In quartz veins of the older rocks, those in the Lower Silurian containing the greatest quantity of gold. Examples are furnished by the auriferous lodes of North Wales.

2. In quartz veins in such Secondary rocks as have been penetrated by certain igneous eruptions, either in the intrusive rock, or in the Secondary strata, and then for a limited distance only beyond the junction of the two rocks. Such an association prevails in California, Central America, and Peru.

3. As auriferous detritus in Secondary and Tertiary deposits, and in the débris and alluvia of rivers, such having been derived from gold-bearing rocks. The *placer* mining of California, Australia, New Zealand, etc., is prosecuted in superficial drift deposits. Gold has been found in streams in Cornwall, Devonshire, Wicklow, and Scotland; and the sands and alluvia of rivers in many parts of the world are washed for this metal.

Our great supplies are drawn from all these sources. The chief are Australia and New Zealand, California and British Columbia, Brazil, Peru, Mexico, and Central America; the Ural, Altaï, and Carpathian Mountains. Gold is also obtained from Thibet, China, Japan, Further India, and Borneo; from the sands of African rivers, especially in Guinea, and from those of the Rhine, Rhone, Danube, and Tagus. Small quantities are procured in mining districts from iron and arsenical pyrites, and other sources, as in Silesia, Saxony, and parts of our own country. The total value of gold imported in 1886 amounted to £13,392,256; while the value of gold exported during the same year reached £13,783,706.

PLATINUM.

Platinum ranks with gold in its resistance to the influence of air, moisture, and ordinary acids, and is the heaviest substance known (sp. gr. 21·5). It is white, exceedingly malleable and ductile, and extremely difficult of fusion. On account of its indestructibility it is of great use in the laboratory for crucibles. It is valuable in the arts, and has been employed for coinage by Russia.

Platinum rarely occurs pure. It is principally found alloyed with palladium, rhodium, iridium, iron, gold, or other metals, and generally in alluvial deposits. In the Ural Mountains it has been observed disseminated throughout the whole mass of certain crystalline rocks. The pure metal is got by adding sal-ammoniac to a solution of the alloy in nitro-hydrochloric acid, and washing and heating the compound thus produced. The sources of supply are the Ural Mountains, Brazil, Peru, Spain, Borneo, and Ceylon. A considerable quantity is also furnished from Russia.

SILVER.

Silver, like gold, is a noble metal, and is used very extensively for similar purposes. It also needs an alloy to harden it; and being less precious, as well as less weighty (sp. gr. 10·5), is more available for common uses, especially many domestic ones. Its chemical preparations are valuable in photography and surgery. In colour silver is a beautifully brilliant white; it is sonorous, highly malleable and ductile, and perhaps the best conductor of heat and electricity.

This metal occurs pure in some rocks in very fine threads, and large masses of pure silver are occasionally met with in veins. But its supply is principally derived from ores, of which the chief are the *chloride* ($AgCl$), or *horn-silver*, a greyish crystalline mass, which looks like horn; the *sulphide* or *silver-glance*, and its combinations with the sulphides of antimony and arsenic, which are known as the dark and light red silver ores; and *argentiferous galena* (sulphide of lead), which often contains very considerable quantities.

Silver is obtained from its ores chiefly by roasting, crushing, and amalgamation with mercury. The separation from lead was formerly effected by the superior affinity of lead with oxygen in the process called cupellation, which was in every way costly; and unless the per-centage of silver in the lead was large, it was not separated. A process known as Pattin-

son's is now employed for desilverising lead; it is based upon the discovery that lead crystallises or consolidates at a higher temperature than an alloy of lead and silver. Consequently, if argentiferous lead be kept at the lowest temperature at which the fluid state could be maintained, solid masses of pure lead are gradually formed and removed, the fluid portion remaining being exceedingly rich in silver. Finally, the lead is subjected to the process of cupellation, and the silver separated.

The most abundant supply of silver is yielded by the mines of Mexico, Chili, and Peru, especially those of Pasco. These mines occur in elevated districts, some upwards of 16,000 feet above the sea-level. Considerable supplies are also obtained from other parts of South America, in the Ural and Altaï Mountains, from China, Japan, Cochin-China, Thibet, Asiatic Turkey, Norway and Sweden, the Harz Mountains, Saxony, Hungary, Austria, and the lead districts of the British Isles.

The total value of silver imported in 1886 amounted to £7,471,639; while the value of the export of this metal for the same year was £7,223,699. Thus the total value of gold and silver imported in 1886 reached the sum of £20,863,895; the total value of the combined export for this year being £21,007,405.

MERCURY.

This extraordinary metal—quicksilver, as it is often called—fluid at ordinary temperatures, is the heaviest liquid with which we are acquainted (sp. gr. 13·59). It becomes solid at $-40°$ Fahrenheit, when it is both malleable and ductile. It is used for the extraction of gold and silver; as an amalgam in chemistry, and in the construction of scientific instruments; in manufactures, for silvering mirrors, and for vermilion; and in medicine, for the valuable products calomel and corrosive sublimate, the subchloride and chloride of the metal respectively.

Quicksilver is met with pure in minute globules, but for the purposes of commerce it is obtained from one of its ores—*cinnabar*, a red sulphide of mercury. This ore occurs in the older rocks, but chiefly in those of the Carboniferous system, and the metal is procured from it by a process of distillation. The principal sources of supply are Almaden in Spain, and Idria in Austria, both very rich; Peru, California, Mexico, Australia, China, Japan, Ceylon, Bavaria, Bohemia, Tuscany, and Hungary; and the quantities of mercury imported in 1886 are about as follows:—

	Pounds.		*Pounds.*
Austria	237,450	Other Foreign Countries	15,000
Spain	3,627,778	South Africa (British)	300
Italy	534,450	British East India (Bengal)	7,500

This very useful metal is rather a rare one. It is but slightly acted upon by either air or water, is of a white silvery colour, malleable, and easily fused. Its specific gravity is 7·3. Besides being largely used in coating or tinning more oxidable metals, as iron, for instance, in the well-known material called tin-plate, and combining as an alloy to form pewter, bell-metal, type-metal, and solder, it is employed in its chemical combinations for a great variety of purposes in the useful arts. It is found as an oxide, chiefly in the metalliferous veins of the older rocks, also in association with wolfram (a double tungstate of iron and manganese), and, like gold, in alluvial districts, as stream-tin.

By the processes of roasting, smelting, and refining, the stream ores produce the grain tin, which is the most esteemed, and the others the bar or block tin. The most productive districts are Cornwall and Devonshire, the Malayan peninsula and islands, especially Banca and Billiton, to the south of it, and Tenasserim, in the East Indies, China, Saxony, Bohemia, Hungary, Peru, New Granada, Bolivia, Mexico, France, Spain, Siberia, and Australia. In 1886 the imports of tin in blocks, ingots, bars, and slabs amounted to 481,528 cwt., valued at £2,318,070. During the same year the total exports of tin amounted to 381,495 cwt., valued at £1,868,089. The quantity of tin used in British industries every year is of course very large.

COPPER.

Copper is a metal of great commercial value, and of very extensive use. It is of a fine red colour, very malleable, ductile, and tenacious, highly sonorous, and a good conductor of heat and electricity. Its specific gravity is 8·96. Independently of its use for coin, sheathing for ships, boilers, and domestic utensils, and of its alloys with gold and silver to harden those metals, copper enters into the composition of brass, bronze, pinchbeck, ormolu, gun-metal, bell-metal, German silver, and the biddery ware of India. It is also largely employed in the production of colours (blue and green), in telegraphy, and in medicine.

It occurs native in fine threads, and occasionally in large masses, the most remarkable of which have been found in Brazil, the district of Lake Superior, and Australia. The principal ores, which occur either in veins or beds, and are most abundant in the Primary rocks, are copper pyrites, a sulphide of the metal combined with sulphide of iron; the red oxide (Cu_2O), the black oxide, the green and blue carbonates of copper, and the purple and grey copper ores, the latter associated with iron, antimony, and arsenic. The reduction of the ores is a matter of some difficulty. In Britain it is chiefly carried on in the neighbourhood of Swansea.

Ores of copper are found in Cornwall, Devonshire, Flintshire, Wicklow, and other parts of the British Isles; Chili, South Australia, the Ural Mountains, United States and Canada, near Lakes Superior and Huron; associated with trap rock in Brazil and Cuba; in the copper schists of Mansfeld, in the Harz, Saxony, and other parts of Germany; in Sweden, Tyrol, Hungary, Tuscany, Spain, Persia, India, China, Japan, Algiers, South Africa, and New Zealand. Malachite, a beautiful ore of copper (carbonate), found abundantly in Russia and Australia, can be used as an ornamental stone. Great Britain receives its supplies of copper chiefly from her possessions in South Africa, Australasia, and North America, besides Norway, Spain, Portugal, Italy, the United States, Venezuela, Algeria, and other countries. The import for 1886 of ore and regulus, wrought and unwrought, and unenumerated manufactures, amounted to 197,600 tons, valued at £4,038,378. The exports for the same year reached 1,135,876 cwt., valued at £2,577,441.

NOTABLE INVENTIONS AND INVENTORS.

I.—PRINTING.

BY DAVID BREMNER.

The art of printing, which has exercised such an important influence on the human race, can boast no high antiquity. It is true that the cutting of wooden stamps for impressing characters upon clay was practised by the Egyptians at a very remote period, and that the Romans used metal stamps for various purposes; but it does not seem to have occurred to either of those ingenious peoples to multiply copies of their writings by a similar method. Printing from engraved blocks was invented by the Chinese about two thousand years ago, and is still carried on with but little change in its methods or appliances. Towards the close of the fourteenth century pictures printed from engraved wooden blocks were produced in various parts of Europe, and were circulated with the view of impressing upon the minds of the people leading incidents in the Old and New Testaments, appropriate passages of Holy Writ being inscribed upon them. But it was not until the invention of movable metallic types that printing was fairly launched on its great career.

To John Gutenberg, a German, the immortal honour of this discovery belongs. The history of this man is much akin to that of other great inventors. When with difficulty he got people to understand the value of his discovery, attempts were then made to rob him of the honour that justly belonged to him. In the year 1450 a partnership into which he had entered at Strasburg for the development of his invention expired, and he removed with all his printing material to Mayence. Here he took a wealthy goldsmith, named John Fust or Faust, into his confidence, and succeeded in inducing him to enter into partnership for the establishment of what was really the first regularly organised printing office. The earliest work undertaken was an edition of the Bible in the Latin language. This celebrated Bible was completed in 1455, and contained 1,274 pages of print. Copies of it are still in existence. Much wonder was excited by the production of this Book; but unfortunately the venture proved ruinous for Gutenberg. He and his partner fell out over financial matters, and he being worsted in a law-

suit, had to forfeit all his property to Faust, who reaped the credit of having produced the Bible. Gutenberg retired into obscurity, and died in 1468, having, during the last three years of his life, received a small pension from the Elector Adolphus. Faust, in the meantime, came to be regarded as a magician or one in compact with the devil, and only escaped consignment to the flames by divulging the secret of the art of printing which he practised. The secret consisted in the employment of movable metal types, and it was only when the mode of using them was explained that the people understood how a person could produce two or more copies of a book exactly similar. The types used were produced by the tedious process of cutting each letter upon a piece of lead of suitable size. A great improvement on this method of type-making was effected by Peter Schœffer, a young man whom Faust transferred from his work as a goldsmith to the printing office after the rupture with Gutenberg. Schœffer conceived the idea of casting the types in a matrix, and thus enormously increased the rate of production. A number of important works were now issued by Faust and Schœffer, who, in order to preserve the secret of the new mode of producing types, put all the persons in their service under an oath not to divulge it. The firm appears to have prospered, and to have preserved their secret until the year 1462, when Mayence was sacked by the Elector Adolphus. That event led to the dispersal into different countries of the servants of Faust and Schœffer, and these persons, considering the oath imposed upon them to be no longer binding, divulged the secret of the new art, and so printing from movable types became known throughout Europe. The forms of the letters adopted by the earlier printers followed closely those used in the manuscript of the period, and attempts were made to imitate the illuminated initial letters of the penmen.

As to the exact date at which the art of printing was introduced into England there is some doubt, and there have been keen controversies on the subject on more than one occasion. Popular tradition assigns to William Caxton the setting up of the first printing press in this country; but an examination of the best authorities leaves little room for doubt that the honour belongs to a man named Corsellis, who had been bred to the printing business in Haerlem, and who had been induced to settle at Oxford at the invitation of two commissioners, one of whom was Caxton, sent over by Henry VI. for the purpose of securing the introduction of the art. At least one book printed at Oxford in 1468 is preserved, whereas it is a well-established fact that Caxton did not begin printing at Westminster till 1471, before which time, and subsequent to the time when Corsellis began operations, a printing office under royal patronage had been established at St. Albans. In due time the art extended to other towns, but for two centuries it did not make rapid progress. After the Revolution in 1688 a demand for books sprang up, and may be said to have gone on increasing steadily to the present time. Side by side with the work of the letter-press printer, the allied arts of the engraver and the etcher have flourished. In both departments there have been many improvements during the present century, and notably during the last twenty years. What the combined arts have achieved it would be needless to point out, as it must be evident to any intelligent person.

Let us briefly describe the operations of the letter-press printer. We must begin with the types, for to them the place of honour belongs. Types are composed of an alloy of lead, tin, and antimony, those metals being chosen because they are easily cast, take a sharp impression, and are not liable to corrode. The antimony, moreover, imparts to the other metals a considerable degree of hardness, and renders the alloy as durable as ordinary brass. Nearly all the types used in books and newspapers are now cast by machinery, and only require to be finished by hand. Hand-casting was a slow, expensive, and unhealthy process, and the machines have proved a boon in every way. There are numerous sizes of type, all made according to standard, and known by distinct names. A complete assortment of types—that is, a collection according to the proportion in which the respective letters are used, is called a "fount." The printer keeps his type in "cases," which are simply shallow wooden trays divided into the needful number of compartments or "boxes." The case in which the capital letters are kept is called the "upper case," because it is placed on the upper part of the "frame," at which the compositor stands; and, in like manner, the case containing the small letters is called the "lower case," because it occupies the lower part of the frame. In the upper case the boxes are all of the same size, but in the lower case that is not so, because the proportions of the letters used render it necessary to have some of the boxes six times larger than others. The largest box is that assigned to the letter e, and the smaller to such letters as j, q, x, and z. For every five hundred of the last-mentioned letters no fewer than twelve thousand of the letter e are required. In the case of capitals there is not such a great discrepancy. The compositor's business is to pick up the types separately between the finger and thumb of his right hand and place them in a small iron receptacle called a composing-stick, which he holds in his left hand. Letter by letter and line by line he goes on following his copy closely with his eye. As he fills his composing-stick, he lifts out the "matter," and places it upon a brass tray called a "galley." When this is filled, a proof is printed and sent with the copy to the "reader" for comparison and correction. The matter is then made up into pages or columns, and sent either to the stereotype foundry or to the machine-room. The stereotyper takes a mould of the page of type by first heating it and then pressing upon it a thick sheet comprised of layers of blotting paper and tissue paper freshly pasted together. This is called the papier-mâché process, and is approved for its expedition and cleanness. When the papier-mâché matrix has been dried, it is placed in a frame, and molten type-metal is run upon it. The "plate" thus obtained, after being trimmed, is placed on the machine, and printing from it proceeds. The advantages of stereotyping are these: it releases the type to be used for other work, it is less liable to displacement on the machine, and it can be stored away ready for use should a demand for more copies of the work than were printed in the first instance arise, whereas to keep the type standing would be both costly and inconvenient.

In printing machinery marvellous progress has been made. The earliest presses were composed of wood chiefly, and the production of a single impression was a clumsy and laborious operation. As the mechanical arts advanced the press was improved, and the newspaper printing machine of to-day is as great an advance upon Caxton's press as the locomotive engine is upon the wheelbarrow as a vehicle of transport. The history of the printing machine is a record of successful struggling with apparently insurmountable difficulties. On the hand press only 250 copies could be printed on one side in an hour, and it will be understood that as newspapers came to have increased circulations this slow rate failed to satisfy. The idea of a rotary printing press was first conceived by Mr. Nicholson, editor of the *Philosophical Journal*, in 1790, and he took out patents; nothing, however, came of the matter. Twenty years later a German named König proposed to the proprietors of the *Times* to construct a rotary printing machine to be worked by steam. He was commissioned to construct two machines on his plan, and they were successfully set to work in the year 1814. The announcement in the paper that it was printed by steam excited world-wide interest. König's machines, however, produced only 1,100 impressions per hour each, and something more expeditious soon came to be desired. Messrs. Applegath and Cowper took up the subject, and produced a machine which delivered the sheets printed on both sides, and which otherwise embodied many improvements. In 1848 Mr. Applegath constructed for the *Times* three printing machines in which many novelties were introduced, and each of which was capable of turning out 12,000 sheets per hour printed on one side. Messrs. Hoe of New York soon afterwards came upon the scene with their famous machines, and as daily newspapers in this country were undergoing rapid development in consequence of the abolition of the paper duty, the advertisement duty, and the compulsory stamp, that firm found many customers. Their eight-feeder machine was capable of producing 20,000 impressions, or 10,000 completely printed newspapers in an hour. The Marinoni machine came next, and produced 20,000 perfect copies per hour. The proprietor of the *Times*, aided by some members of his mechanical staff, constructed, in 1872, a machine which effected a great saving of labour. This machine, known as the "Walter Press," feeds itself from a web of paper wound upon a roller, and delivers 17,000 perfect copies per hour.

Web printing machines are now used in the offices of all newspapers of large circulation, and some of them not only fold the paper, but in the case of eight-page journals, cut open the pages, and paste one sheet within the other. Side by side with this advance in newspaper printing machinery the appliances of the book and magazine printer have undergone improvement. It was at one time thought that illustrated works could be printed only on the hand press, but now they are turned out in the most perfect manner on rotary machines. Much ingenuity has been expended in the construction of presses for jobbing work, and with the most satisfactory results. Special machines for printing and numbering railway tickets at a high rate of speed have also been introduced.

So far we have been dealing only with printing from types, or stereotype plates; but we must mention also lithographic printing, which in these days represents a large amount of work. Much of the stationery used in commerce is printed by the lithographic process, and so are maps, plans, and illustrations of many kinds. The capabilities of the art are well shown in the Christmas and New Year cards which have in recent years become fashionable media for conveying messages of greeting and good wishes. In lithography, as the word implies, the drawing is made on a stone, of peculiar quality, and impressions are taken off it with a printing press of special construction. Coloured work requires a separate stone for each colour, and the colours are impressed in succession, it being no uncommon thing for a card to go through the machine a score of times before it is completed. Printing from copper or steel plates differs from printing from woodcuts or stones in this respect, that whereas the device to be impressed is in the case of the latter two raised upon, or even with the surface, in the former it is sunk. In preparing a steel or copper plate for printing, the printer rubs it over with ink so as to fill the lines. He then wipes off the ink from the surface, leaving the lines fully charged. A sheet of paper is now laid on the plate, and the two are passed through a press of special form, with the result that the paper is pressed into the lines and absorbs the ink which they contain. There are other modes of printing in use, but as they are only modifications of those described above we need not allude to them further here.

CIVIL ENGINEERING.—I.

By E. G. Bartholomew, C.E., M.S.E.

INTRODUCTION—EARLY HISTORY OF THE SCIENCE.

Civil Engineering is a term so comprehensive as almost to defy a complete and detailed explanation, whilst its importance is only equalled by its comprehensiveness. Its history is even more difficult to deal with, for it runs parallel with almost that of the world itself. Some idea of the scope of this vast science may be formed by stating what are some of the subjects it embraces; for it must not be imagined that the building of bridges, and the formation of canals and railroads, constitutes the whole of the occupation of the civil engineer.

The civil engineer is one who applies the principles of mechanical and physical philosophy to the construction of the machines and public works by which the arts and accommodation of civil life are rendered more efficient, extensive, and secure; and hence Civil Engineering is the term applied to that science which treats of the construction of canals, railroads, roads, bridges, gas and water works, sewage and drainage works, aqueducts, piers, harbours, docks, viaducts, lighthouses, breakwaters, and such like. Each of these subjects involves an acquaintance with detail in their design and carrying out which is by no means apparent on the surface. For instance, in the one subject of *drainage* is involved the arrangement of the dams, sluices, syphons, and machinery of every kind, whether actuated by steam-power, water-power, or the wind, for removing the surplus water, and the canals which communicate with every part of the district to be drained. The civil engineer must be acquainted with all the principles and details of machinery, which is after all but the handmaid of civil engineering, and must be enabled to utilise it to the utmost for facilitating and economising his work. He must also be practically acquainted with the strength of materials, and with those principles of combination by which the greatest amount of strength is gained with the least expenditure of material. He must also have a clear knowledge of brickwork and masonry, and carpenter's work in general. From the foregoing it is evident that the occupation of the civil engineer is far from limited, and that his attainments, if he would excel, must not be few. He must be a man of strong determination to combat with the difficulties he is sure to encounter, and one of ready thought to devise expedients to overcome them. Inasmuch as the civil engineer must be well acquainted with mechanical engineering, and not altogether ignorant even of many points of military engineering, he stands at the head of his profession, and the vastness and variety of his works render a merely superficial acquaintance with details useless to him; and no man need aspire to any eminence as an engineer who has not climbed the ladder of experience from its lowest round. Some of our best engineers have been men trained in the school of the hardest manual labour, and have risen step by step, gaining experience at each advance, and employing that experience to the development of further achievements; and it is a fact that all our most celebrated engineers have made themselves conspicuous by works essentially their own.

It may, under certain circumstances, be desirable for an engineer to have the assistance of an *architect;* but that engineer who is able himself to proportion his structures to the rules of architecture, and to produce a work as elegant as it is useful, and as useful as it is solid, has an immense advantage over others. Similarly, as many of the public works which the civil engineer is called upon to carry out involve very largely the employment of machinery, both in the course of the work and permanently afterwards, an intimate knowledge of mechanism and mechanics is of the utmost value to him; and certainly no individual is so well qualified to adapt mechanism to the particular function it is intended to perform as the man who undertakes the general design. The architect and the mechanician have each their sphere of usefulness, and very many works are required in which architecture or machinery alone is needed. Such works are not, strictly speaking, in the province of the civil engineer to carry out.

One more remark we would make is that an intimate acquaintance with *geometry* is indispensable for the civil engineer to possess. His operations are very frequently of such a nature as to need great strength, and structural strength necessarily implies that a strain has to be withstood. The engineer must therefore be prepared to meet any strain that may be applied, in the most effective and economical manner. Any unnecessary use of material must be avoided, and therefore, particularly where lightness has to be combined with strength, a clear knowledge of direction of force and strain is an obvious necessity.

That civil engineering is certainly one of the most ancient, if not *the* most ancient of all the sciences, is evident from the magnificent relics which continue, after the lapse of thousands of years, to be the wonder and admiration even of the present age. No doubt the different conditions of society at different periods of the world's history have caused various modes of development of the science of engineering. In the earlier ages war engrossed more attention than the arts of peace, and we might expect to find more attention paid to the arts of war in those days; and hence the works of the early engineers would embrace the defence of their cities by the erection of massive walls and towers, or the construction of engines to demolish them. But although many of the arts of peace may have lain dormant for a while, commerce was not neglected; and we find the Phœnicians, who were the earliest traders on record, more than 1,200 years before Christ, settling upon the coasts of the Mediterranean, building Sidon, Tyre, and other coast-towns, and forming moles and harbours for the protection of their shipping, and for facilitating their loading and unloading. The defence and siege of Tyre (332 B.C.) form most interesting records of early engineering—not, perhaps, strictly *civil*, but nevertheless, a record of ingenious devices to meet emergencies which many a modern engineer would do well to study. When we turn to Egypt we are again met with most remarkable remains of early engineering skill. One of their monarchs, Menes, who lived 2,320 years before Christ, actually diverted the course of the Nile, and, by cutting water-courses and raising embankments, converted the immense marsh which existed upon both sides of the river into the finest agricultural district in the world.

The great lake Mœris, which, according to Herodotus, was

450 miles in circumference, was artificially constructed, and intended as a vast reservoir to receive the overflowing water of the Nile, that it might be subsequently utilised for irrigation. This great work of engineering was accomplished 1385 B.C. The canal which connected the lake with the river still remains. That remarkable work of modern engineering, a work recently completed, the Suez Canal, was accomplished by Ptolemy II. hundreds of years prior to the Christian era. A passing remark is all we can give to the Pyramids—those stupendous works of ancient engineering which, from their construction, must have called into action the highest skill of the Egyptian engineers. These royal sepulchres are not entirely composed of huge blocks of chiselled stone, but are built upon a core or foundation of the original mountain, the native rock itself being excavated to form the burial-chamber; and the manner in which the large masses of stone which form the facing of the rock were cut, carried, and lifted to their respective levels, furnishes an interesting study for the engineer. The Great Pyramid contains at the present day more than six millions of tons of hewn stone.

The Pharos, or lighthouse of Alexandria, built by that celebrated civil engineer, Sostratus, was considerably higher than St. Paul's Cathedral. It was constructed entirely of stone, and divided into five storeys. But the engineering works of the early Egyptians were not confined to masonry. The people were acquainted with metallurgy and hydraulics. The process of refining gold and silver, and the forging of iron, werepractised by them largely. It is not surprising that the science of hydraulics reached an advanced stage in a country so intimately associated with water supply, and the advantages and disadvantages connected with it. To bring the forces of Nature to serve the convenience of man is one of the great aims of the engineer, and this the ancients knew well how to effect. Naturally, Egypt was a marsh; hence their engineers raised dams and banks to restrain the river within bounds. But Egypt altogether without the Nile would be a barren waste, lying as it does under almost a tropical sun, and rarely watered by a shower; hence the Egyptians made lakes and canals to irrigate the land; and to avail themselves of the water when sunk below the level of the soil they devised engines, influenced by wind or water, whereby the lowered waters of the river might be raised, and poured again upon the thirsty soil.

We pass on now to Greece, and here we find engineering directed principally to the erection of temples, and buildings for the celebration of religious rites, chaste and beautiful, but grand and massive; not that the ancient Greeks by any means neglected either commerce or the arts of war. They built magnificent walls to protect their cities from the incursions of man, and capacious harbours to guard their ships from the assaults of Nature. To Hippodamus, a celebrated Greek engineer, the city of Rhodes owed its beauty. Philon and Callicrates were Greek engineers, who lived about 400 B.C. The siege of Rhodes by Demetrius, and its defence by Diognetus and others, form an interesting record of the advance of civil and military engineering in those early times. But probably no individual of the period was so truly an engineer, in the strictest sense of the word, as Archimedes, a man fruitful of resources, and quick of invention, many of whose contrivances are employed to the present day. He was as clever as a mechanician as he was correct as an engineer; and the combination of these two sciences in his person, and the success resulting therefrom, form the best proof we can have of the advantage to be gained in all engineering matters by uniting theory and practice. The stately Parthenon, and other grand Grecian temples, are, it is true, rather monuments of architectural than engineering skill; but the man who could design and erect such massive edifices would require to be an engineer of a high order. To *design* an architrave 21 feet long, 5 feet 8 inches wide, and 6 feet 9 inches deep, might be easy; but who shall estimate the skill requisite to convey a single block of stone of these dimensions to the spot, and elevate it to its site more than 40 feet from the ground—a block containing 803 cubic feet, and weighing at least 50 tons!

But we must not linger amongst the relics of engineering art in Greece. There are greater works to be found in Rome and its neighbourhood, and Vitruvius has left us much information of Roman engineering works, many of which have in part or altogether disappeared.

Conscious of the advantage derived from the selection of a healthy site for their towns, the Romans were very careful to avoid such places as, by their natural position, would render a discharge of sewage a matter either of doubt or difficulty. In this respect the Romans were in advance of ourselves, for we select our position and *afterwards* endeavour how best to drain it, and if the general level prove lower than the means of discharge we are compelled to erect costly machinery to convey it away. The Romans were equally alive to the importance of a good water supply. If, from other causes, they desired to build upon a badly-watered locality, they expended incredible labour, and spared no expense to bring water to their town; and the aqueducts of the Romans are to this day standing monuments of engineering skill. The engineering works of the Romans were not confined to any particular region. Wherever their arms carried conquest, there they displayed the same wonderful ingenuity. The whole of Europe abounds more or less with the remains of the labours of their engineers. Their walls, their gates, their harbours, their temples, bridges, roads, aqueducts, public buildings, the materials they employed, their triumphs over Nature, the height of civilisation they attained to, are all so many proofs of the advanced state of civil engineering science amongst them. Their introduction of the arch in masonry is in itself a memorial to their engineering greatness; for although the existence of the arch in some of the pyramids of Egypt points to an era far before the building of Rome, yet it must be remembered that the Egyptian arches were constructed rather as ornaments, or as covers to sarcophagi, than as the bearers of superincumbent weights, and that therefore the true value of that form was unknown to the Egyptians. But look how profusely arches are made use of in the amphitheatre of Vespasian, where they stand tier over tier; see the wonderful lightness and immense strength of that enduring monument, so perfect after the lapse of eighteen centuries! What work of modern engineering skill do we find to compare with it?

Modern engineers have followed the plan adopted by the Romans, of forming breakwaters by the immersion of large blocks of stone or concrete, piling them up without regard to order, until they appeared above the water. Of course the base of such a structure is greatly larger than the top, but the prismatic form thus obtained conduces greatly to its stability and strength. Plymouth breakwater is constructed thus, and is only a reproduction of the breakwater at Centocella, now Civita Vecchia.

The Romans eminently excelled in their roads. As a rule these roads were carried forward in a straight line, regardless of all natural obstacles. They are to be found in almost every country of Europe, not excepting our own. Twenty-nine great military roads centered in Rome, and extended thence to the utmost limits of the empire. They were most substantially constructed, and profusely decorated on both sides with temples and other ornamental structures. The Romans are stated to have constructed about 53,000 miles of road. The description of the Appian Way reads almost like a fable. It was 360 miles long, and paved throughout with large blocks of stone, squared and dressed with the chisel, and so intimately united that the interstices between them are scarcely visible. When the roads passed through towns they were built upon vast sewers, which effectually drained their streets.

The bridges built by the Romans have withstood the storms and floods which have carried away many a modern structure. Their aqueducts are marvels of engineering skill, and evidence a perfect knowledge of hydrostatics and hydraulics. The finest of these were the Aqua Claudia, which was fifty miles long, and conveyed water to the capital from Porta Maggiore, and the Anio Novus, sixty miles in length, six miles of which were carried upon arches, some being 100 feet high.

Not only were the Romans exceedingly particular in their choice of sites for their towns and cities; but if necessity compelled them to select a position too contiguous for health to marshy ground, they in the most complete manner removed the evil by an elaborate system of drainage. Rome itself was perfectly drained, most of these subterranean channels remaining to the present day. Tunnels, some of great length, were amongst the engineering works of the ancient Romans. The temples built for their gods, although not equal in massiveness to the temples of the Egyptians, yet far excelled them in magnificence and architectural beauty. Indeed, in all the works

of the Roman engineers we trace a master hand. Centuries have elapsed since they were completed, and although discoveries have since been made, and many great works carried out, we must still yield the palm of merit to the Romans in almost all points of structural and architectural engineering.

Our brief history now passes in silence over several centuries. From the decay of the Roman empire to the middle of the fifteenth century the arts were in a declining state, and little or nothing of an engineering character was undertaken. The first revival of civil engineering in Europe took place in Holland, when the known rich and valuable character of the low-lying land adjoining the sea-coast, and subject to the overflowing of the tides, began to attract attention, and the idea of reclaiming it from the German Ocean was entertained. We merely refer to this now as a matter of history, that the first engineering works of more modern days have been those of drainage, which in the case we have alluded to consisted of the twofold operation of erecting a barrier against the encroachments of the ocean, and then removing the enclosed waters. Indeed, so important was this kind of work, and so valuable the results, that for a long series of years, both in this country and on the neighbouring coasts of Holland, this was the only work of an engineering character attempted. It was owing to the great success which attended the efforts of the Dutch engineers, that some of them, particularly Vermuyden, were invited to England to superintend the drainage of the great fen district in Norfolk, a work which the Romans attempted, but without success.

But we now enter upon a period when we are enabled to give a more connected and detailed account of our own engineering works, premising, however, that as our object in the succeeding chapters upon this subject is to explain the principles and practice of the various branches it may be divided into, we shall only allude to particular works of an engineering kind which have been carried out, in order better to illustrate the subject.

TECHNICAL DRAWING.—II.

TECHNICAL DRAWING BOX—TECHNICAL PENCILS—HINTS ON COLOURING DRAWINGS—LINEAR DRAWING BY MEANS OF INSTRUMENTS.

THE writer has frequently been asked by students, "Which is the *cheapest* box of instruments to get?" whilst others have put to him the question, "Which is the *best* case to buy?" Now, it is not within the province of this work to recommend the instruments of any particular maker, nor to suggest the prices which should be given, as this last depends on the means at the command of the purchaser. But smallness of price is not always real cheapness, and a good article, manufactured by, and bearing the name of, a respectable English house will be found by far the most economical in the end.

Of course the price of a case of drawing implements must depend on what is contained in it. The following articles are indispensable; and these having been obtained as a beginning, single instruments or colours can from time to time be added as occasion may require:—A set of instruments, which should at least comprise a pair of compasses with steel, pencil, and inking leg; a draw-pen; a twelve-inch rule, divided into eighths or tenths on the one side, and twelfths on the other; if possible, a protractor; and certainly a stick of Indian ink. In addition to these, the mechanical draughtsman requires colours; and, proceeding again to name the *smallest* stock he can do with, we advise him to get at starting three only—viz., indigo, lake, and yellow-ochre—from which he will be able to mix most of the tints used in Technical Drawings, according to methods which will be given presently. Of course he will add to the three colours from time to time. Then he will require a small slab—one with three divisions will be found the most useful—and a few brushes with sticks.

As to pencils, the degrees most generally useful are those marked HB and H, the latter of which, being harder than the former, is more adapted for very minute work; but, as a rule, hard pencils are not the best for mechanical drawings which are to be inked, as they are liable to make grooves in the paper, the bottom of which the nib of the drawing-pen does not touch, and hence the edges of the line will be ragged; and further, lines which are drawn with very hard pencils are difficult to rub out. For mechanical drawing, it is best to cut a *flat* point to the pencil; this is done by cutting away the wood, and leaving about an eighth of an inch of lead projecting, which is then to be cut until it is thinned to a flat, broad point like a chisel; the broad side of this point is moved along against the rule, and the line thus drawn will be found to be much finer than one drawn with a round point. The chisel-point is economical in various ways, for it will not break so often, and the point once cut can be rubbed from time to time on a piece of fine glass-paper or a file, or even on the edge of the drawing-paper.

Many of our readers will have experienced the annoyance of a point breaking in the midst of a lesson, just at the moment when following the teacher's illustration line by line. The student is therefore recommended to employ two pencils of the same kind, and to make a point at *each end* of *both* before beginning to work; to keep the spare pencil at his side; as the point he is using becomes blunt or breaks, he turns his pencil; and when the same occurs to the second point, he takes up the spare pencil. He has thus the use of four points, more than which he is not likely to want in one evening.

Once again the student is urged to remember that the mere possession of a case of instruments, however good, will not constitute a draughtsman. The instruments are merely the tools—the mechanical agents through which the mind acts; and it cannot be denied that the more the mind comprehends of the subject to be drawn, the more willing and intelligent servants will the hands become, and the more accurately will they guide the compass or the drawing-pen. Geometrical drawing, then, should be looked upon as a mental exercise more than a merely manual occupation or employment, giving us not only subject for thought and earnest reflection, but enabling us to communicate our plans to others in such a manner that they can understand us and work out our designs better than they could have done from the most eloquent description.

The student will, no doubt, find it difficult at first to draw very fine lines, or to get them to intersect each other exactly as required, especially if he has been engaged in some hard manual occupation during the day; but he will find a little practice will soon overcome this, if he but starts with patience, energy, and the earnest desire to excel.

A FEW PLAIN HINTS ON COLOURING DRAWINGS.

When you are about rubbing up some colour, first see that the slab is not dusty. Then drop some water on it from one of the larger brushes; but on no account dip the cake of colour into the cup or glass of water, which is a most wasteful plan, as it softens the cake, and causes it to crumble off in rubbing.

Rub the paint firmly, but not too heavily, or you will not get the colour smooth. Be careful to hold the cake upright, so as to keep the edge flat.

When you have rubbed as much colour as you think you are likely to want, do not at once put the cake back into its place in the box, but stand it on one of its edges so as to allow it to dry, otherwise it will stick to the box.

Blue, *red*, and *yellow* are called the three *primary* colours. When *two primaries* are mixed they *produce a secondary colour*. Thus:—

Primaries.		*Secondary.*
Yellow and Red	produce	Orange.
Yellow and Blue	„	Green.
Red and Blue	„	Purple.

When you wish to mix a secondary colour, such as green, from the two primaries blue and yellow, rub the blue in one division of the slab, and the yellow in another, leaving a space between them. Then, with your brush, mix the two colours in this vacant space; but on no account rub either of the cakes in the colour obtained from the other, as this would leave the end soaked in another tint, and when you used it again you would find the colour would be impure. Of course, these remarks apply to the mixing of any two colours.

In order that colour may flow easily, and cover a surface evenly, it is necessary that it should be thin. It is always easy to wash it over again if it is not dark enough, but it is very difficult to wash off the colour if it be too dark.

When you have laid on your colour, do not touch it again whilst wet. If it should require re-touching, let this be done

when it has dried, as you will generally make it worse by stirring about in the wet colour, and will be likely to rub up the surface of the paper.

Wherever it is possible, use a large brush in preference to a smaller one, as you will by this means be the more likely to succeed in getting a flat wash, whilst a small brush might make the tint lie in streaks. Care is, however, necessary in using a large brush, so that you may not pass over the outlines.

To lay a flat wash of colour is of great importance, and to be able to accomplish this some practice is required, in order to obtain which you are recommended to draw several triangles, squares, or other figures, of different sizes. Commence by colouring the smallest, and then work on in order of size, as it is more difficult to spread the wash over a large than a small surface. Let your brush be quite full of thin colour, and, holding it nearly upright, pass it boldly over the upper part of the figure; then gradually bring the colour down, spreading it equally over the whole work as rapidly as you can, so as to prevent, if possible, any one part drying before the whole surface has been covered with colour.

The following is a list of the colours used by most architects to express the various substances:—

Material.	*Colour.*
Brickwork to be executed (in the plans and sections)	Crimson Lake.
Brickwork in Elevations . . .	Crimson Lake mixed with Burnt Sienna or Venetian Red.
The lighter Woods—such as Fir.	Raw Sienna.
Oak or Teak . .	Vandyke Brown.
Granite . . .	Pale Indian Ink.
Stone generally .	Yellow Ochre, or Pale Sepia.
Concrete Works .	Sepia with dark markings.
Wrought Iron .	Indigo.
Cast Iron . .	Payne's Grey, or Neutral Tint.
Steel . . .	Pale Indigo tinged with Lake.
Brass . . .	Gamboge, or Roman Ochre.
Lead . . .	Pale Indian Ink tinged with Indigo.
Clay or Earth . .	Burnt Umber.
Slate . . .	Indigo and Lake.

Having thus given a few of the elementary principles of drawing and colouring, we will now proceed with our subject, showing the application of these principles, and developing others as the lessons advance.

The principles of foundations being enunciated in the lessons on "Building Construction," it is here proposed to give some studies of the various assemblages of timber employed in such works, in order to afford some useful practice in drawing parallel lines at right angles to each other.

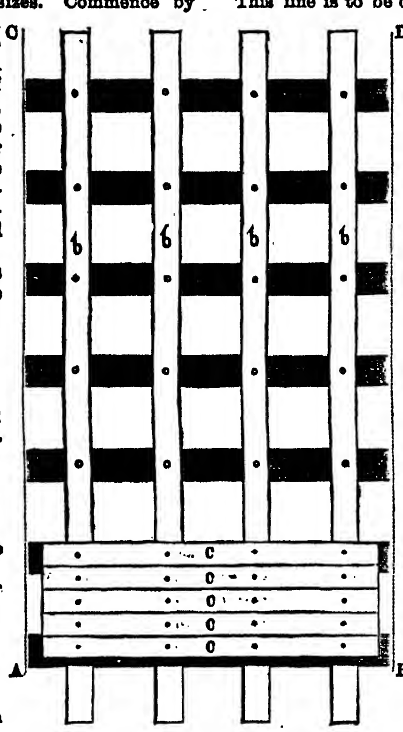


Fig. 4.

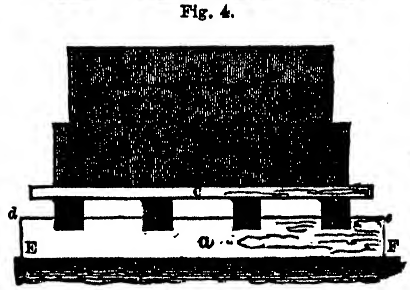


Fig. 5.

LINEAR DRAWING BY MEANS OF INSTRUMENTS.

Fig. 4 is the plan of a network of timber supporting a platform on which a foundation is to be erected.

Here the transverse sleepers, *a a a a*, rest directly on a site which, although not soft enough to render piling necessary, is still not sufficiently firm to allow the walls of the structure to be raised without the foundation being extended and equalised.

Fig. 5 is the sectional elevation of the sleepers and wall, *a* being the elevation of the cross-sleepers, which are shaded in the plan.

With thus much information as to the meaning of the subjects before him, the student can now commence work; and as we have often known learners waste half of their evening, and when reproached with idleness, say, "I don't know where to begin," we may here, once for all, lay down the principle, that when the general position of the whole subject on the paper has been decided upon, the sure plan is to *draw first* that which would be *laid down, or built first*. It is also necessary to say that all the drawings in these lessons are to be worked to at least twice the size of these examples.

Well, then, the sleepers, *a a a a*, would, of course, be laid down first; and therefore these must be drawn first.

Draw the line A B, the front edge of the first cross-sleeper (Fig. 4).

This line is to be drawn with the T-square, holding the butt-end tightly against the left-hand edge of the drawing-board. Do not draw it exactly the length of A B, but longer, and set off the length A B upon it, leaving a little of the indefinite line on each side of A B. The purpose of this will be pointed out to you presently.

Next, keeping your T-square in its place against the edge of your board, move it by its butt-end a trifle lower down, place your set-square against it as shown in the cut, and draw perpendiculars from A and B (as shown in Fig. 4). The immediate purpose of these is to give the ends of all the cross-sleepers; but as they will be wanted for another purpose by-and-by, draw them much higher than they are for the present required: in fact, in all architectural drawing, it is very useful to draw your *pencil* lines *past* their absolute extremities, for reasons which I will explain to you when speaking of inking the drawings.

You will now find it useful to employ two pairs of compasses or dividers. In the one, take the thickness of the sleepers; and in the other, the width of the space between them. From A B set off on the perpendicular, A C, the width of the first one, then a space, then another sleeper, and so on; and draw the lines which give the edges of the sleepers.

It will, of course, be remembered that too hard a pencil should not be used, so that the superfluous lines may be easily rubbed out after inking, and that the pencilling must be done as lightly as possible, so that no more of the grit of the lead than is absolutely necessary may be left on the paper, for this will work up between the nibs of your draw-pen, and cause endless annoyance and difficulty.

With the same width in your compasses, mark off the sizes of the longitudinal sleepers, *b b b b*, which rest on *a a a a*; and across these again draw the planking, *c c c c*, the lines forming the ends of these planks to be drawn within the lines A C and B D.

To draw the sectional elevation (Fig. 5), draw the ground-line, E F, and the line above it, *d e*, representing the height of the cross-sleepers, of which *a* is the elevation.

Produce the lines of the longitudinal sleepers in the plan; these will give the sides of their sections in Fig. 5, and across these draw the edges of the planking, *c*, parallel to the lower sleeper. It will be seen that the under sides of these sections are lower than the upper edge of the lower sleeper; this is because they are notched on to it in the manner shown in the lessons on "Building Construction."

On the platform thus constructed draw the section of the pier or wall.

It may be mentioned that the spaces between the sleepers should be well rammed or flushed up to the top of the sleepers —the planking may be then said to rest upon a solid basis— and planks should be spiked to the sleepers with wooden pins.

APPLIED MECHANICS.—I.

BY ROBERT STAWELL BALL, M.A., LL.D.,
Astronomer-Royal for Ireland.

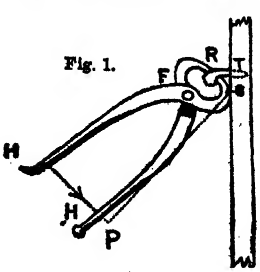
APPLICATIONS OF THE LEVER AND THE SCREW.

It is proposed in this series of lessons to give an account of the practical applications of mechanical principles. The general laws of Mechanics have been already laid down in our "Lessons in Mechanics" in The Popular Educator. Our business is with the application of these laws to practice, and therefore we shall not unfrequently have to refer to them. For example, in the present lesson we shall often assume that the reader is familiar with the different forms of lever and their mechanical properties, of which an account will be found in Lesson IX. of the series referred to. So also in what we shall have to say of the applications of the screw, we shall suppose that the reader already possesses the knowledge which may be gained by a perusal of Lesson XV. Occasional glances have been given in these lessons of the useful applications of the mechanical powers. It shall be our duty to follow out the useful part to its details. We shall describe and give a practical account of many tools, implements, and machines; we shall select those which are of interest either from the fact that they are of very extensive use, or that they are connected with some important branch of manufacture. We shall occasionally describe a very common tool, and occasionally a colossal machine or structure. It is hoped that an account such as this is designed to be will not only prove of interest to the student of Mechanics, but be of actual service to those who are in any way connected with manufacturing industry.

The lever is susceptible of a vast variety of forms, and it will be useful for the student to practise himself in trying to recognise its presence under its different aspects. In machines of any complexity, which contain a great number of moving parts, many of these parts are levers of one form or another. We shall mention a few of the different cases in which this contrivance is met with.

We begin with one that is very simple and well known—the ordinary pincers. This is shown in Fig. 1, in which the familiar process of pulling out a nail is represented. This tool consists of two levers of the first order; the common fulcrum of both is the pin at F, about which they work. The power is applied at H, by squeezing the ends of the levers together. The load is at R, and consists in the grip with which the nail is held. In the figure the leverage is about sixfold—that is, the jaws grip the nail with six times the force that the ends, H, H, are forced together. The nail is held in the jaws by friction, which increases with the pressure, and consequently, the more powerful the force with which the jaws are pressed together, the more secure is the hold which they have of the nail. Hence we see the principle of the lever of the first order applied in taking hold of the nail, and we shall now recognise it in the subsequent process. When the nail is to be extracted, the side, s, of the jaw is pressed against the surface, and s becomes now the fulcrum. H is pressed down towards the surface by the hand, and this pressure constitutes the power. The load to be overcome is now the tenacity with which the nail resists being withdrawn. This is principally due to the friction of the nail upon the wood into which it has been driven, and of course varies with the nature of the wood and the size of the nail. We shall take one instance. It has been found that a nail called a threepenny brad, which is 1·25 inches long, when hammered to a depth of 0·5 inch into dry Christiana deal, required a force of 58 lb. to extract it. Let us suppose that it is a nail of this size which we have represented in the figure. Now, the action of the hand is twofold—it first squeezes the jaws together, and then, while holding them firmly, presses the whole tool in the direction of the arrow on H H. It is only the latter part of the action of the hand that we are at present concerned with. Let [illegible] by the principle of

Fig. 1.



the bent lever, the power of the hand must be to the resistance of the nail, as the line S T is to the line S P. Now, on the scale on which the figure is drawn, S T is about one-eighth part of S P; hence the power necessary to be applied at H is only 58 ÷ 8, that is, about 7 or 8 lb. There is another advantage gained by the use of this tool, which it is important to notice, as the same case is met with in many different tools and machines. The pincers enable the whole power of the arm to be concentrated on withdrawing the nail. The fingers applied directly would be bruised in fruitless efforts even to stir the nail; but the pincers, by giving a good object to grasp, enable the whole power of the arm to be applied, and then they magnify this power eightfold. No wonder, then, at the remarkable efficiency of this useful tool.

Levers are not unfrequently used when there is no mechanical advantage to be gained in the way of power, but where the direction of a force is desired to be changed. In such cases it is sometimes a little difficult to see that the piece is a lever. We must then carefully remember the definition, that a piece capable of turning around a centre, to one point of which the power is applied, while to another point the load is applied, is a lever. A common illustration of this form is shown in Fig. 2, which represents the well-known bell-crank. Bell-wires being stiff and rigid, it would be impossible to change their direction by means of pulleys, and so the beautiful and ingenious contrivance of the bell-crank has been adopted. It consists of a quadrant, usually of brass. It is supported at the centre, F, upon a pin which is firmly fastened to the wall, and about this pin it is free to turn. The power is applied to the circumference of the quadrant at the point P, the direction of its application being perpendicular to the radius F P; this is the point to which the wire is attached by which the pull is given. Now, the effect of the pull on P is to turn the crank round slightly in the direction of the arrow, and this can only be done by raising R; hence at R the wire to transmit the pull is attached. The load is in this case only equal to the power, so there is no gain in that respect; in fact, if anything, there is a slight loss, owing to the friction of the crank about the pin.

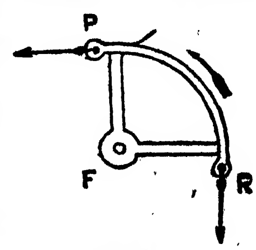


Fig. 2.

A very useful application of the lever of the third order is met with in the common treadle used in turning the foot-lathe. Here the power consists of the pressure of the foot which is applied between the fulcrum at one end, which is the centre about which the treadle moves, and the load at the other end, which is communicated by means of the connecting-rod and crank to the main shaft of the lathe. The power is here diminished, as is always the case in the lever of the third order; but the object aimed at is convenience, and it is found by experience to be easier for the foot to exert a pressure sufficient to move the lathe through a short distance, rather than a less pressure through a longer distance. The real resistance which the lathe has to overcome is not the raising of a weight, but the shearing force necessary to cut off with a tool shavings of wood, ivory, iron, or other work on which the lathe may be engaged. The lathe apparently gives an increase of power, because in turning iron, for instance, the shavings that are cut off are far greater than could have been removed from the work by the direct application of the tool. One reason of this is, that in the latter case only a few muscles of the hand and arm can be employed, while, with the aid of the lathe, all the powerful muscles of the leg can be concentrated on the work.

The screw is a mechanical power of the utmost importance. Its theory has been already given in Lesson XV. of Mechanics (Popular Educator, Vol. IV., p. 11), and we shall now point out some practical considerations in connection with its use.

The efficiency of the screw is largely diminished by friction. In fact, sometimes the power of a screw is found to be only one-fourth of what it would have been had not this force been present. This contrasts the screw with the lever, for in the latter the effect of friction is quite imperceptible. Theory at once in the lever gives the relation between the power and the

load; so does theory in the screw also; but then it must be preceded by and based upon actual experiment.

In order to make this clear we shall fully describe experiments which have been made upon a screw-jack, with a view of determining the relation between the power and the load.

The screw-jack employed is represented

it tripod

of iron, two legs of which are shown in the figure. The top of this, A, is made of brass, and forms the nut of the screw. The screw itself is very carefully turned from a cylinder of wrought iron. Its pitch is two threads to the inch, and its diameter about two inches. The top of the screw is enlarged, as seen at B. This contains two holes, one of which is shown, while through the other the arm B E is passed. This arm is for the purpose of turning round the screw. At C is the crown. This is so arranged that it can turn round on B, so that after it has bitten into the surface which is being pressed upwards it shall cease to revolve, though B is turned round. The object of this is to diminish the great friction which would be experienced by making the top revolve against the surface, and placing the friction instead between the top of the screw and the under surface of the crown, where it can be reduced by having a smooth and well-oiled bearing. Another reason is, that the surface acted on would be torn and injured by the action of the crown. There are slight ridges round the margin in order to make it take firm hold. The bottom of the tripod is also furnished with short projecting points which embed themselves in the surface and prevent the tripod from turning round with the screw.

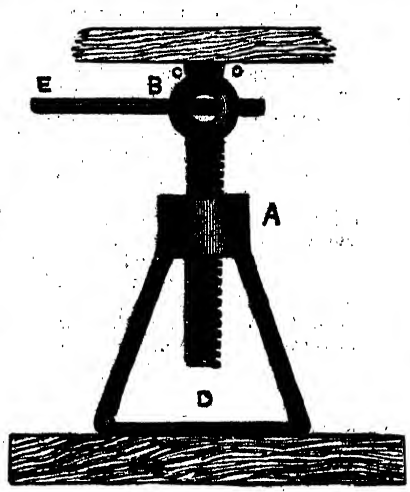


Fig. 3.

The screw-jack used in the experiments now described was one adapted for weights up to two tons. The arm is about 33 inches long. When the arm makes one revolution it moves through a space of

$$2 \times \frac{22}{7} \times 33 = 208 \text{ inches.}$$

But it must perform two revolutions in order to raise the screw 1 inch. Hence the power must have been exerted through a distance of 416 inches to raise the screw 1 inch. According, therefore, to the principles laid down, if there were no friction the mechanical efficiency of this screw should be 416-fold. Let us see how much it is in reality.

A weight of 1,000 pounds is placed upon the screw, and it is found that a power of 8·2 pounds applied to the extremity of the arm is just sufficient to raise it. Hence the real mechanical efficiency is—

$$\frac{1000}{8 \cdot 2} = 122 \text{ lb.}$$

In fact, since $\frac{12200}{416} = 29$, the true mechanical efficiency is only 29 per cent. of what it would have been had there been no friction—less, in fact, than one-third.

It is important to understand this thoroughly, and in general it will be safe to calculate on not getting from a screw more than one-fourth of the power it would yield without friction.

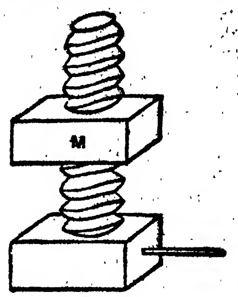


Fig. 4.

The most useful contrivance by which the different parts of a structure can be united together owes its efficiency to the screw. This is the well-known screw-bolt represented in Fig. 4. Bolts are the stitches by which machines are put together. They owe their utility to several distinct reasons.

1. They enable the parts to be drawn together very forcibly. Thus, suppose a bolt have ten threads to the inch, and that its nut be turned by a wrench, the arm of which is a foot long, the hand must move in one revolution through a circumference of

22

Hence, when the nut has been moved one inch, the hand must have moved 754 inches. This would be the mechanical efficiency without friction; with friction it may be assumed about one quarter of this, or 188. Hence, in order that the nut may exert a pressure of one ton in drawing the surfaces together, it is only requisite that the hand exert a pressure of

$$\frac{2240}{188} = 11 \cdot 9 \text{ lb.}$$

Thus, with a force of 12 lb., which can be exerted with little effort, the parts are pulled together by a force of a ton; and with a little exertion a force four or five times this amount is readily produced.

2. The strength with which they hold the parts together is very remarkable. Not only does a bolt bring the parts into intimate contact, but it keeps them there. In fact, if the screw be properly made, and the size of the nut properly proportioned, the bolt may be considered as formed of solid iron when once the nut is screwed home. But wrought iron, when good, requires a force of about twenty tons per square inch of section to tear it asunder; consequently a nut whose diameter is an inch will not be overcome by a force less than about fifteen tons. Though the two means just mentioned are the most important, yet there are several subsidiary reasons why bolts are so extensively used.

3. Their simplicity. A bolt consists only of two parts, for the nut requires no catch to prevent it from slipping back along the screw after it has been brought home. This is due to friction. Without friction every nut would require to be provided with some complicated arrangement to prevent its motion. Bolts connecting parts subject to extreme vibration can generally have their nuts kept tight by the simple process of screwing a second nut down home on the top of the first.

4. Another great practical convenience of bolts is the very different sizes of the work they can grasp. A bolt 12 inches long, and with 2 inches of screw on the end, can bind together any two pieces whose united thickness is a little greater than 10 and a little less than 12 inches. But with the simple addition of washers—which are little iron plates with holes large enough to allow the bolt free passage—a 12-inch bolt can be made to grasp any two pieces whose united thickness is less than one foot.

5. Bolts require very little to be done to the work to which they are applied. All that is necessary is that a hole be bored large enough to admit the bolt. It is not necessary that this hole fit closely; a loose fit acts as well as a tight one.

6. Nor do bolts injure the work when the pressure is applied to them, because by the use of washers of proper size the force can be distributed over a sufficiently large area on the surface of the work, and consequently bruising it can be avoided.

7. Bolts can be very readily applied, removed, or changed, and only a most simple tool—a screw-wrench or spanner—is necessary for the purpose. No skilled workman is required.

8. Bolts being made of wrought iron are everlasting if rust be prevented. They are very cheap, as thousands of tons of iron are annually manufactured into bolts by machinery. They are kept in stock, of all sizes and forms, in shops where they are sold, and they are very portable.

These reasons being considered, we need not wonder at the enormously varied circumstances under which bolts are employed; they lead us with a heavy debt of gratitude to that most beautiful of the mechanical powers—the screw.

Little need be said of the common wood-screw. The thread of this screw is sharp, as it has to cut a nut for itself in the wood through which it passes. Its point must first be inserted into a hole, some of its threads then embed themselves slightly in the wood, and thus form the beginning of a nut. When the ewdriver is applied the screw advances, and thus makes its nut more perfect. It may be remarked that a screw should always be at right angles to the grain of the wood, so as to

enable the thread to insinuate itself between the interstices of the fibres. It is obvious that this cannot be done properly if the grain be parallel to the axis of the screw.

We shall conclude this lesson with an account of a common and useful machine, which combines in itself examples both of the lever and the screw. This is the vice, of which, in its ordinary form, a diagram is given in Fig. 5. It consists of two jaws, A B and A′C. A B is continued downwards into what is called the tail, F, which rests upon the ground. The object of the tail is to support the vice when, as is often the case, the work between the jaws at W receives a blow from a hammer. A′ is firmly secured to the bench by means of a strap of iron, T, which passes around it, and is then bolted to the bench at D. Thus the jaw A B is fixed; while the other jaw A′C is capable of turning around the pin shown at A′. Thus C can either be brought into contact with B, or removed to a considerable distance from it. The object of the vice is to seize the work, W, and hold it very firmly while it is being filed, or drilled, or cut with a chisel, or undergoes some other operation. Of course, it is only for comparatively small pieces of work that such an instrument is used or, indeed, required. The necessary pressure is given to the jaw A′C by means of a screw, S. In Fig. 6 are shown the pieces of lead which are used for putting on the jaws of the vice when holding work which would be injured by the steel faces of the vice if unprotected.

Fig. 5.

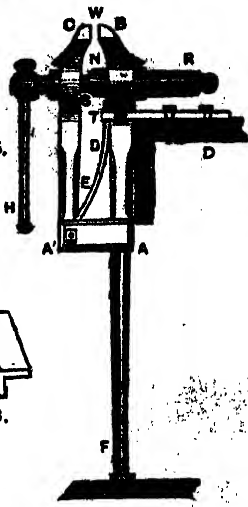
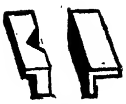


Fig. 6.



When the handle, H, is turned so as to move the screw into the nut, the jaw A′C is brought forcibly towards A B. A′C is then a lever of the third order, as the fulcrum is at one end, the load at the other, and the power in the middle. The power of the screw is therefore slightly diminished, when applied to the work at C; but as a force of a ton or more can easily be exerted by the screw, it will, even though it loses a third of its amount by the nature of the leverage, exert a tremendous pressure on the work. The surfaces of the jaws are roughened, so that they can take a firm grip of what is between them, and hold it by the friction. At E, a spring acting upon the jaw A′C is shown. The object of this is to move the jaws asunder when the pressure of the screw is relaxed. The screw and its nut are quite independent of the jaws, and require to be renewed occasionally, as the thread of the nut is apt to wear out by constant use.

There are multitudes of other applications of the screw and lever, and it will be useful for the student to exercise himself in endeavouring to examine them.

ANIMAL COMMERCIAL PRODUCTS.—II.

CARNIVORA.

DIGITIGRADA (*continued*).

The Tiger (*Felis tigris*) inhabits the Asiatic continent, and is especially abundant in Hindostan. He is nocturnal in his habits, and during the day generally lies asleep in some shady spot, gorged with his last meal. He frequents the neighbourhood of springs and the banks of rivers, where the weaker animals, forced by the scorching heats of the tropics, seek coolness and drink. The skin is a bright tawny yellow, shaded into pure white beneath the body, and beautifully marked with dark bands and stripes. It is used to cover the seats of justice in China, and is also employed for rugs and mats. From 200 to 250 tiger-skins are annually imported into the United Kingdom.

The Leopard (*Felis leopardus*, Cuvier).—This animal is found in Africa and India; it inhabits the deepest recesses of the forest, thus rendering pursuit nearly impossible. Taken usually in traps, it is also hunted with dogs, until, being an expert climber, it takes refuge in a tree, and when the hunters come up it is easily shot. The skin is a tawny yellow, the lower parts white, and covered all over with dark spots, which vary in size and form. It is worn as a mantle by the Hungarian nobles who form the royal body-guard of Austria; it is also used as a saddle-cloth in some of our cavalry regiments, as a mark of rank amongst the officers. About 200 leopard-skins are sent annually to the English fur market.

The Jaguar, or *American Panther* (*Felis onca*, Linnæus).—A native of the warm parts of America, especially Paraguay and the Brazils. Next to the tiger, the strongest species of the genus; also an expert climber. The skin is beautifully marked with deep chocolate-brown spots upon a rich yellowish ground. From 300 to 400 skins of this animal are annually imported, and used as rugs, or for ornamental purposes.

The Puma, or *American Lion* (*Felis concolor*, L.).—Extensively distributed throughout the Southern American continent, found also in the warmer parts of North America. More frequently met with in grassy plains and marshy meadow-lands bordering rivers than in the forest. This animal lives upon deer, hogs, and sheep, to which it is very destructive; for it is not satisfied with the simple seizure of prey, but, meeting with a herd of animals, will kill as many as possible, sucking only a portion of the blood from each. The fur of the puma is thick, close, and reddish-brown in colour, changing on the belly to a pale reddish-white. The skin, when imported, is used for carriage wrappers.

The Canadian Lynx (*Felis Canadensis*, Geoffroy).—This is a timid creature, common in the wooded districts of Canada as far north as 66°, incapable of attacking the larger quadrupeds, but well armed for the capture of the American hare, on which it principally feeds. It makes a poor fight when attacked by the hunter, spits and sets up its hair like an angry cat, but is easily destroyed by a blow on the back with a slender stick. From 15,000 to 20,000 lynx-skins are annually sent over to this country by the Hudson's Bay Company.

The Common Cat (*Felis domesticus*, L.).—In Holland the cat is bred for its fur, being fed on fish, and carefully tended until it arrives at perfection. We import annually 20,000 cat-skins, and the English fur-market also receives a considerable quantity from home. The cat's skin makes an excellent rubber for electrical machinery, and is also used for sleigh coverings, railway rugs, etc.

The Family CANIDÆ (Latin, *canis*, a dog) forms the next group of Digitigrade Carnivora, and includes dogs, wolves, and foxes. The different varieties of dog are supposed by some naturalists to have been derived from the wolf. The common dog (*Canis familiaris*, L.) is distinguished from the wolf and jackal by its recurved tail; but the species vary very much in size, form, and the colour and quality of hair. In most collections of fur a few dog-skins will be found, although there is no regular trade in them.

The *Wolf* (*Canis lupus*, L.) has a valuable skin. This animal, once indigenous to this country, but now exterminated, still lingers in the forests of Northern and Southern Europe, and is particularly abundant in Russia, North America, and the northern parts of Asia. From 9,000 to 10,000 wolf-skins are annually imported from Europe, the United States, and British North America. They are serviceable for the linings of coats and cloaks, for sleigh coverings, and wherever additional warmth is desirable.

The Red Fox (*Vulpes fulvus*).—It is not the common European fox that is found in the furriers' shops of this country, but different varieties of the American (equally well known for its cunning and mischievous attacks on the poultry-yard). The fox is easily distinguished by its long, sharp nose and bushy tail. Foxes have been formed by zoologists into a distinct group amongst the *Canidæ*, or dogs, on the ground that the pupil of their eye is vertical, whilst in the dog it is circular. The tail of the fox is longer and more bushy, its head broader and more pointed in the muzzle, and its gait and attitude crouching. The red fox of America is ferruginous in colour, and strongly resembles the fox of Europe. About 8,000 skins are annually imported into England, most of them to be re-exported, chiefly into the markets of Turkey.

The Cross Fox (*Vulpes decussatus*).—This is probably only a

variety of the red fox. It is distinguished by a black cross on the neck and shoulders, and is a South American animal. Its skin is valuable, selling for £4 or £5.

The Arctic Fox (*Vulpes lagopus*).—This animal is very common within the Arctic circle, and exhibits in a remarkable manner that mutation of colour which polar animals undergo with the change of the seasons. In winter it is a pure white; in summer a dorsal line of a darker colour is observable, with transverse stripes upon the shoulders. This circumstance has led to its being mistaken for the cross fox. Late in autumn these animals collect in vast numbers on the shores of Hudson's Bay, and migrate southward, returning early in the following spring along the sea-coast to the northward. The southern limit of their migrations in North America is 50° north latitude. The Arctic fox is very cleanly in its habits, very unsuspicious, and easily snared. There is a dark variety known as the sooty or blue fox (*Vulpes fuliginosus*). Both the blue and the white skins are imported in considerable quantities, but they do not fetch so high a price in the English market as the skins of the red fox.

The Black or Silver Fox (*Vulpes argentatus*).—This species is distinguished from the others by its intensely black fur, which is intermingled with silvery hairs, and has a white spot at the end of the tail. It is a native of the northern parts of the American continent. "An unusually fine skin of one of these animals has been sold in London for £100. The imperial pelisse of the Emperor of Russia, made of the black necks of the silver fox (exhibited at Hyde Park, in 1851), was valued at £3,500."

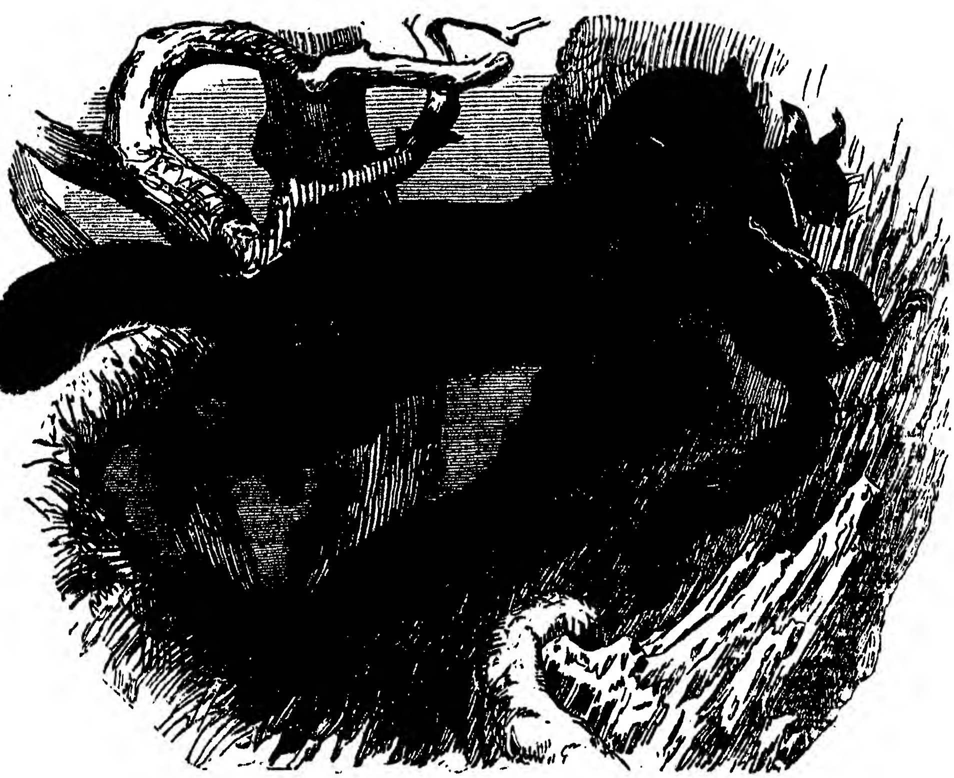
(*Vulpes Cossac*).—This fox inhabits the vast plains of Tartary. Its skin, which is of a clear ferruginous-yellow colour, is much prized in Russia and Turkey. Not fewer than from 40,000 to 50,000 of these animals are annually taken and sold.

The Family Mustelidæ (Latin, *mustela*, a weasel) forms the last group of Digitigrade Carnivora whose skins supply our fur markets. This family includes the sable, polecat, weasel, otter, and wolverine. These animals, from their peculiar appearance and habits, have been called vermiform quadrupeds. They are distinguished by the length and slenderness of their bodies, which enable them to wind like worms into very small openings and crevices, whither they easily follow the smaller mammalia and birds on which they prey. Several of them, as the polecat, emit a very offensive odour; nevertheless, they yield the most costly and highly-prized of our furs.

The Ermine (*Mustela erminea*).—This, the most interesting species of the weasel family, resembles the common English weasel, and inhabits Siberia, Russia, Norway, and Sweden. In winter it is clothed by Nature with a fur as white as the snow which then covers the ground, and is thus rendered invisible to its numerous enemies; in summer its garb changes to a dingy brown.

The white fur of the ermine is highly esteemed. It is the royal fur of England, and of the sovereigns and emperors of Europe. The Pope and his cardinals have their ecclesiastical robes adorned with capes and trimmings of ermine, according to their rank. The tail alone of the ermine is jet black, and this is inserted at intervals into the prepared furs as an ornament.

"In England there is now no restriction on the wearing of this fur, but in the reign of Edward III. it was forbidden to all but the royal family, and a similar prohibition still exists in Austria. There is, however, a characteristic distinction made in the mode of ornamenting the fur employed on state occasions, according as it is worn by the sovereign, or by peers, peeresses, judges, etc. The sovereign and royal family can alone wear ermine trimmings in which the fur is spotted all over with black—a spot in about every square inch of the fur. These spots are not formed of the tail of the ermine, but of the paws of the black Astracan lamb. The crown is also adorned with a band of ermine with a single row of spots. Peeresses wear capes of ermine, in which the spots are arranged in rows, the number of rows denoting their degrees



THE RUSSIAN SABLE (MUSTELA ZIBELLINA).

of rank. Peers wear robes of scarlet cloth, trimmed with pure white ermine without any spots. But the number of rows, or bars of pure ermine, in this case also denotes the rank. The robes of judges are also scarlet and pure white ermine."* The number of ermine skins annually imported is upwards of 100,000, and of these very few are exported. The fur of the ermine is manufactured into ladies' muffs, tippets, trimmings, and linings.

The Russian Sable (*Mustela Zibellina*).—This is the next fur to ermine in value and in general use. The animal which yields it lives in the wilds of Siberia, and is hunted in the depths of winter, when its fur is most valuable. The fur is brown, with some grey spots on the head. The darkest in colour are the best. The skins are small, but they are sold at prices varying from three to ten guineas. Not much more than 2,000 of these valuable furs are received in England, because so much prized in Russia, where about 25,000 skins are annually collected.

This fur is usually manufactured into linings, sometimes valued as high as 1,000 guineas. The Lord Mayor, aldermen, and sheriffs of the City of London have their robes and gowns lined with Russian sable, according to their respective ranks. 206,000 marten skins were imported. Of these the greater number belonged to this species.

The *Polecat* (*Mustela putorius*) is common throughout Europe. It is very destructive in the poultry-yard, and very courageous. Its flexibility is so great, that when seized improperly by a terrier, or not griped in the right place, it will turn and fasten on the dog, so as to prevent further attack. This animal has a soft black fur, with a rich yellow ground. The natural odour of the fur is unpleasant, but in preparing it processes are adopted which effect its removal. 150,000 to 200,000 of these skins are annually sold in the London fur markets. The finest are obtained in Scotland. More than 25,000 are exported yearly from this country to America, where the fur is much sought after.

The *Pine Marten* (*Mustela abietum*, Ray) is found abundantly in the forests of Northern Europe and America. It shuns the habitations of man, and preys on birds and the smaller animals —mice and hares. When its retreat is cut off, it shows its teeth, sets up its hair, arches its back, and hisses like a cat. Upwards of 100,000 pine marten skins are annually imported into England from the territories of the Hudson's Bay Company and Canada.

The Beech Marten (*Mustela Foina*).—This animal has a white

MUSTELA ERMINEA AND MUSTELA VULGARIS IN WINTER.

throat, and is thus distinguished from the pine marten, the throat of which is yellow. It is found in woods and forests in Northern Europe, but nearer the habitations of man than the pine marten. It is imported in considerable quantities from the north of Europe, and its fur is dyed to imitate sable.

The tails of sables are used in the manufacture of artists' pencils and brushes.

The Minx (*Mustela vison*).—This animal is a native of North America, and its skin comes to us principally through the Hudson's Bay Company. In the month of March this Company holds annually, in London, a public fur sale, which attracts great numbers of foreigners. Through them the furs destined for the Continent find their way to Leipsic, whence they are distributed throughout Europe. The fur of the minx resembles the sable in colour, but is considerably shorter and more glossy. It is much used for ladies' wear, and is made into victorines, cloaks, muffs, etc. In a single year, the number of skins of this little animal received in this country have amounted to a quarter of a million. Their price varies from ten to fifteen shillings a-piece. When this skin is of a silver-grey colour, it is additionally valuable. A muff made of six of such skins is worth twenty-five guineas.

The American Sable (*Mustela leucopus*).—The fur of this animal varies from a tawny colour to a deep black. The animal itself is known by its white feet. The fur is much worn in England, and is made into cuffs, muffs, and boas. In 1856,

The Stone Marten (*Mustela saxorum*).—This animal is distributed throughout Europe. Its under fur is bluish-white, with the top hairs a dark brown; its throat a pure white, by which it is generally distinguished. The French excel in the art of dyeing this fur, and for that reason it is frequently sold under the name of French sable.

The Tartar Sable (*Mustela Siberica*).—This little animal is caught in the northern parts of Russia and Siberia. The fur is bright yellow, the colour being remarkably uniform all over the body. The skin is used both in its natural state and dyed; the tail is employed for artists' pencils. In 1856 we imported as many as 70,000 skins of this animal.

The Woodshock, or *Pekan* (*Mustela Canadensis*).—The pekan inhabits North America, and is also called Hudson's Bay Sable. As the natural colour of this skin is much lighter than the prevailing taste, it is dyed of a darker hue. Thus treated, it is scarcely inferior to the Russian sable, which it is intended to imitate. We import annually about 18,000 of these skins.

* "Cyclopædia of Useful Arts." By Charles Tomlinson. Vol. I., p. 729.

BUILDING CONSTRUCTION.—II.

SCALES.

It has already been said that block plans, elevations, etc., are drawings which show the whole property, building, or machine, and that working drawings are executed of a larger, in fact, sometimes of the real size of each portion, so as to guide the workman.

Now it will be clearly understood that although the drawing may be much smaller than the object it represents, it must, for any useful purpose, have all its parts in proper proportion; and not only this, but the drawing must be made in such a manner that it may at once be evident what the true size would be. This is called the "scale."

TO CONSTRUCT A PLAIN SCALE.

Let it be required to construct a scale of 1 inch to the foot. This has been taken for the first example, owing to its great simplicity; for it will be at once understood that a 12-*inch* rule will represent 12 *feet*, and therefore the drawing executed on this scale will be *one-twelfth* ($\frac{1}{12}$) of the real size. This is called the *representative* fraction. Draw a line of any length, and mark on it several inches. Mark the left-hand end of the line 0, the first space 1, and so on. This, however, only gives *feet*; it is necessary, therefore, to divide the inches into twelfths,* and then each twelfth will represent an *inch* of the real measurement. It will be obvious that the same principle will apply to the construction of scales, whatever the representative fraction may be; thus—

TO CONSTRUCT A SCALE OF $\frac{1}{120}$,

that is, one of *one-tenth* of an inch to the foot; because there are 10 tenths in an inch, and 12 inches in a foot. Draw a line of indefinite length, and mark off on it any number of tenths of an inch; these will represent feet. It is not necessary to figure every division, nor to carry them beyond 10 feet in single feet; after that they may be marked in 5-feet lengths.

Of course, on such a small scale separate inches would not be required; it is only necessary, therefore, to divide one of the tenths into four parts, each of which will represent *three* inches. The detail would then be drawn on a larger scale, as already explained.

GENERAL PRINCIPLES OF BUILDING CONSTRUCTION.

The term *construction*, as applied in practical art, is generally understood to mean *fabrication* rather than *form*, its object being the adaptation of such materials as are most fitted for the purpose intended, and the art of the constructor being devoted to combining them so as to ensure permanency and stability.

If an upright wall be properly constructed upon a sufficient foundation, the combined mass will retain its position, and bear pressure in the *direction* of *gravity* to any extent that the ground on which it stands and the component materials of the wall can sustain. The aim of the constructor then must be, first, to secure a firm basis on which the fabric is to rest, and secondly, so to dispose his structure, and so to combine all the parts, that the whole pressure may act in the required direction: for instance, when a building is to be roofed, the rafters, if butting merely on the top of the walls and meeting at the ridge, would of course be liable to press the wall outward. The constructor, therefore, designs a "truss" in a manner best adapted to the particular case. A truss consists, in the first place, of a tie-beam, which is a strong piece of timber. The lower ends of the rafters are mortised into this, and their upper ends are inserted into the top of an upright piece called a "king-post," which, acting as a keystone of an arch, keeps the rafters in their places; whilst their lower ends, being inserted into the tie-beam, *cannot* spread outward. A firm triangular assemblage of timbers is thus formed, and when this is raised to its place on the walls, there is not any pressure *outward*, the entire weight bearing *vertically*, that is, in the direction in which the wall is best calculated to bear it; and should the design of the building not permit of the introduction of the tie-beam, the constructor applies buttresses outside the walls, to enable them to resist the thrust caused by the weight of the roof. The numerous ways in which scientific construction is practically applied in building, will be exemplified according to the requirements of the different materials treated of in the following pages; and we will proceed, in the first place, to speak of

FOUNDATIONS.

By the term *foundation* is meant—

1. The surface or bed of earth on which a building rests; and

2. The manner in which the lower portions of the building are constructed so as to afford the best possible bearing for the superstructure.

Foundations are spoken of as (1) *natural* and (2) *artificial*.

Although both these terms seem self-explanatory, it is still deemed advisable to refer briefly to their exact signification in accordance with the principle adopted in this series of papers; viz., not to assume any previous knowledge; and although this plan may be open to the objection that information may be supplied which many students have already acquired, yet this is by far safer than that any one who may be totally unlearned on the subject should seek information in these pages and be disappointed.

A *natural* foundation, then, is such as will be found where the site is underlaid by a solid rock, or any kind of incompressible, resisting substances, free from water. Of course this must depend entirely on the locality; and it must be borne in mind that it is not so important that the ground should be perfectly rocky and hard, as that it should be compact and of similar consistence throughout; it is not so necessary that it should be absolutely *unyielding* as that it should yield *equally* throughout.

Artificial foundations are such as are *constructed* so as to render the ground, which is too soft to bear the building, fitted for the purpose required. Of course the means adopted must depend on the situation, the nature of the soil, the character or purpose of the building, etc.; and some of the methods mostly used will be here described and illustrated.

Bad foundations have been the cause of the ruin of many modern buildings. This has arisen from the costly nature of the work in making good the site, when the soil is not naturally suitable. But it is clear that the saving of the first expenso is an unwise economy, as the entire stability of the superstructure necessarily depends on the firmness of the foundation.

The first process in connection with laying the foundations is sinking the trenches in which the bases of the walls, etc., are to rest, and in digging out the hollows for cellars, etc. This is called the *excavation*.

If the surface be found to be perfectly rocky, or to consist of a gravelly soil embedded with stone, it becomes a good natural foundation when it has been reduced to a level. If the soil prove generally firm, the looser parts, if not very deep, may be dug up until a solid bed be reached, and the hollow may then be filled up with broken stones and concrete; if the soil be not very loose, it may be made good by ramming into it large stones, closely packed together, or dry brick rubbish widely spread; but if the ground be very bad, it must be piled and planked, or covered with a bed of concrete, according to the circumstances.

In a building to be erected on a slanting site, the foundation must rise with the inclination of the ground, which must be "benched out"—that is, cut into a series of broad steps; this will ensure a firm bed for the courses, and prevent them from sliding, as they would be likely to do if built on an inclined plane.

When a good hard foundation is easily accessible, as solid gravel, chalk, or rock, we have nothing to do but to excavate the surface mould to the sound bottom, and build at once, first putting in the "footings," which are one or more courses forming a sort of steps, each projecting a little beyond the other. These footings will be referred to and illustrated further on. On hard ground, one course of masonry, about half as wide again as the wall, is ample, but of course this must depend on the discretion of the architect. The rule, however, which must always guide the builder, is that the broader the base the safer the construction, and therefore the softer the ground, the wider it will be necessary to spread the foundation; and thus on softer ground, in many cases, footings have been employed

* To divide a line into any number of equal parts, see "Lessons on Practical Geometry," page 64.

extending not only double the width of the wall, but even more.

But the invention, or rather the re-introduction of concrete, has altered much of the system formerly adopted. When the ground is a deep clay, the building material, be it what it may, should go so deep as not to be influenced by changes of temperature or the rising or falling of springs, as the alternate shrinking or swelling of the ground must affect the stability of the building. It has been satisfactorily proved that in this country frost seldom penetrates beyond a foot into the ground, but in clayey soils, cracks and fissures, caused by the drying of the ground, frequently extend to the depth of two or three feet. Under such circumstances the bases of the foundation should be below such level. If the ground be springy, it should be drained, if possible; if not, a foundation must be laid with concrete as low as the lowest level of the water, or, if very deep and boggy, *piles* must be used. The plan of building on sleepers or planking has now been almost entirely discarded; for experience has shown that timber, where exposed to alternations of wet and dry, soon rots, and is liable to be crushed, thus allowing the walls to sink. Where the ground is wet at one time and dry at another, the best timber soon decays, and therefore piles used in supporting buildings should, where possible, be so placed as not to be liable to such alternations.

The use of concrete, except under very peculiar circumstances, has entirely superseded all other substances used in artificial or semi-artificial foundations. Concrete may be defined as a sort of rough masonry, composed of broken pieces of stone or gravel, not laid by hand, but thrown at random into the trenches, cemented together with lime in various ways, and thoroughly mixed with it before it is thrown in.

In England, the lime is generally ground, and mixed, when hot, with the stones. In France, however, the lime is first made into a paste, and the mixture is called *béton*. *Béton* has been much used in foundations of breakwaters, bridges, etc., as it has the property of hardening under water. The use of this composition is of very ancient date, and many examples of its use by the Romans still remain to us on the coast of Italy; it is supposed to be the "Signinum opus" mentioned by Vitruvius.* It was in very common use in the Middle Ages, walls, and even arches, having been frequently made of it. Smeaton† states that he was induced to use it from his observation of the ruins of Corfe Castle,‡ in Dorsetshire.

Dance, the architect of Newgate Prison, employed a sort of concrete in rebuilding that structure in 1770-78. The site of part of the new building was a deep bog, and it was rendered available by shooting a quantity of broken bricks into the holes, mixed with occasional loads of mortar, in proportion of 4 to 1, and suffering them to find their bed.

Any hard substance, broken into small pieces, will serve for the solid part of concrete. That most used is gravel or ballast. This should not be sifted too fine, as the sand which is left will mix with the lime, and form a sort of mortar, and so assist to cement the stones together. If broken stones or masons' chips are used, it is well to mix some sharp sand with them. The general rule is, that no piece should exceed a hen's egg in size. In this country, the lime is generally ground, and used hot. It is mixed with the ballast by scattering it amongst the stones, and turning them over with a shovel, water being at the same time thrown upon the mass. It is then immediately filled into the trenches. This has sometimes been done by shooting it from stages erected for the purpose. This practice has, however, been much and justly censured by the greatest engineers; the proper method being to put the concrete down in layers of about one foot in thickness, to level each course, and ram it well down. In support of this plan we may quote the words of Mr. George Burnell, C.E. (on limes, concretes, and cements): "In almost every work upon the art of construction we meet with descriptions of modes of making concrete. It is, however, very discouraging to observe that, in spite of all that may be said, the majority of architects and engineers treat the matter with such utter indifference that the old imperfect systems are still retained, and the conduct of these works is left almost invariably to some rule-of-thumb workman, who only knows that he has been accustomed to make concrete in a certain manner, without knowing any one of the principles which regulate the action of the materials he works with. We thus find that the bulk of the concrete made in and near London, where the building art ought to be the most advanced, is made simply by turning over the ground stone-lime, a very moderately hydraulic one, by the way,* amongst the gravel. It is then put into barrows and shot down from a stage. Such a mode of proceeding is rapid and economical, but it is eminently unscientific, leading, doubtlessly, to the waste of material we so often witness; for the practice is to make the concrete about one-third thicker than would be at all necessary if the process of making it were more perfect. It cannot be too often repeated, that the first condition necessary to obtain a good concrete or *béton*, is that the lime should be brought to the state of a perfect hydrate,† before being mixed with the nuclei‡ which it is to surround. It should, therefore, be reduced to the state of a thick paste, and made into a mortar, before it is mingled with the gravel. Instead of being thrown down from a height, and left to arrange itself as it best may, it should be wheeled in on a level, and beaten with a rammer; for we find that when thrown thus from a height the materials separate, and the bottom parts of a thick bed of concrete are without the proper proportion of lime. The advantage of making the lime into mortar previously, is that it fills in a much more perfect manner the intervals of the gravel or stones, and, in fact, renders the concrete what it is meant to be, an imperfect species of rubble masonry."

Where the soil consists of running sand or soft clay, the area of the foundation must be enclosed by sheet piling. This consists of piles driven close to each other, so as to form a wall which encloses the soil, and prevents the softer portion from spreading out under the superincumbent weight of the building. Sometimes as much as possible of the soft matter is removed and replaced by *béton*, or concrete, the heads of the piles sawn off level, and a kind of wooden platform built on this support. In other cases piles may be driven in at certain distances apart over the entire area enclosed by the sheet piling, the spaces between these piles being filled in with stones or concrete, and a solid flooring constructed on this foundation.

It may be remarked that concrete is now used in making the walls of buildings as well as their foundations, the walls being raised about one or two feet at a time by throwing concrete into a frame-work or box formed of iron plates, which is raised from time to time as often as is necessary until the wall has been built up to the height required.

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* Vitruvius, Marcus, a celebrated Roman architect, who was born about 80 B.C. He received a liberal education, and pursued those studies which were calculated to fit him for the profession of an engineer and architect, and was engaged in the Roman army as superintendent of military engines. He wrote a work called "De Architectura," in ten books, treating of the different branches of architecture and civil engineering.

† Smeaton, John, an eminent civil engineer, was born at Austhorpe, near Leeds, in 1724, and early showed a bent towards mechanical pursuits. In 1755, an event occurred which was to afford him the opportunity of reaching the very summit of his profession. The second wooden lighthouse which had been erected on Eddystone rock (which is one of a group of rocks daily submerged by the tide, situated in the English Channel, nine miles off the Cornish coast) was destroyed by fire. The speedy re-erection of another beacon was of the utmost importance, and the execution of the work was entrusted to Smeaton. The new lighthouse was built of stone. The cutting of the rock for the foundation commenced in 1756; the building was executed between June, 1757, and October, 1759; and the lantern lighted on the 16th of October of that year. A new lighthouse was erected on the Eddystone in 1879-82, the ravages of the sea having rendered the foundations of Smeaton's great work insecure.

‡ This castle stands in the middle of a village, to which it gives its name. In the vicinity are stone and marble quarries, clay works, and potteries. The castle was founded in the tenth century, and was long one of the strongest fortresses in the kingdom. Here King Edward the Martyr was murdered by his mother, Elfrida, about A.D. 979; and King John, during his disputes with the barons, kept his regalia here for safety. Here, also, in 1643, Lady Bankes defended the castle for six weeks against the Parliamentary forces. It was dismantled in 1645.

* *Hydraulic lime* is such as possesses the quality of setting or hardening under water.

† *Hydrates* are substances in which a definite quantity of water is chemically combined with a definite quantity of some other constituent.

‡ *Nuclei*, plural of *nucleus*, a substance, however small, which forms a centre around which other matters gather.

PROJECTION.—III.

PROJECTION OF PRISMS—SECTIONS.

A PRISM has already been defined to be a solid whose opposite ends are equal and similar plane figures, and whose sides uniting the ends are parallelograms. It will be clear, then, that the lessons previously given are but stepping-stones to the present, and we can therefore at once proceed to

PROJECTION OF PRISMS.

To Project a Square Prism.—Width of side ½ inch, length 1½ (or 1·5) inch. The prism is in this lesson placed so that its axis is vertical, and its long faces are at 45° to the vertical plane.

Draw the square, Fig. 21, which is the plan of the prism, its sides being at 45° to the intersecting line; perpendiculars drawn from the angles will give the edges of the elevation, which are to be terminated by an horizontal line at 1½ inch from the base.

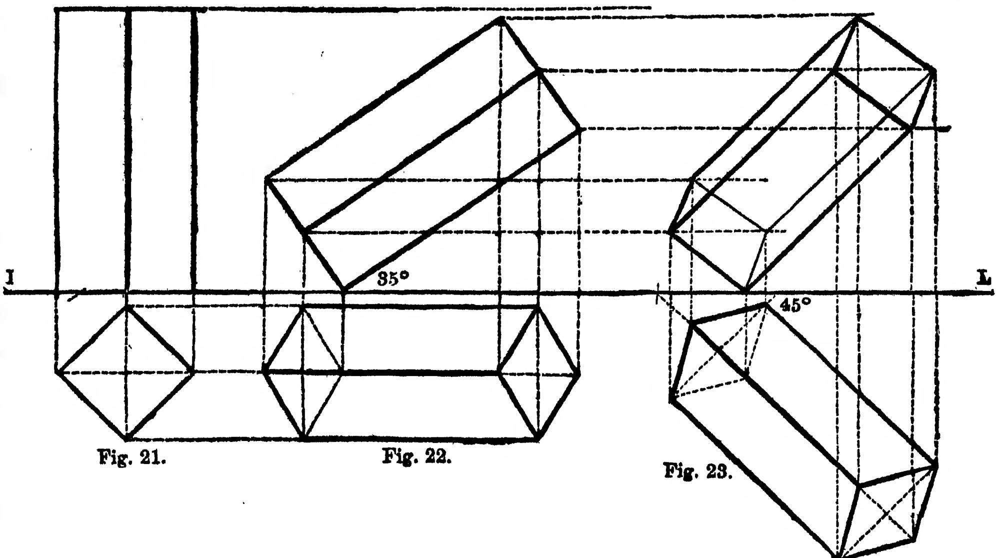


Fig. 21. Fig. 22. Fig. 23.

Fig. 22.—It is now required to draw the elevation and plan when the axis, although remaining parallel to the vertical, is at 35° to the horizontal plane. Now it will be evident that as far as the elevation is concerned, it will merely be altered in *position*, not in *form*, which change is effected by allowing the object to rest on one angle of the base, and continuing the motion until one edge of the elevation (the edges being parallel to the axis) is at 35° to the horizontal plane. It will therefore only be necessary to copy the previous elevation, inclining it at the required angle. This motion, however, whilst causing so slight an alteration in the elevation, causes an entire change in the plan; for whilst in the first position the plans of the edges were mere *points* (see Fig. 1), which united form the base, the square of the top being immediately *over* this, as in a line placed vertically, the upper extremity is directly over the lower; but the moment the line is inclined, the plan, which was previously a point, becomes a line, the length of which increases as the object approaches the horizontal. (See Fig. 4.)

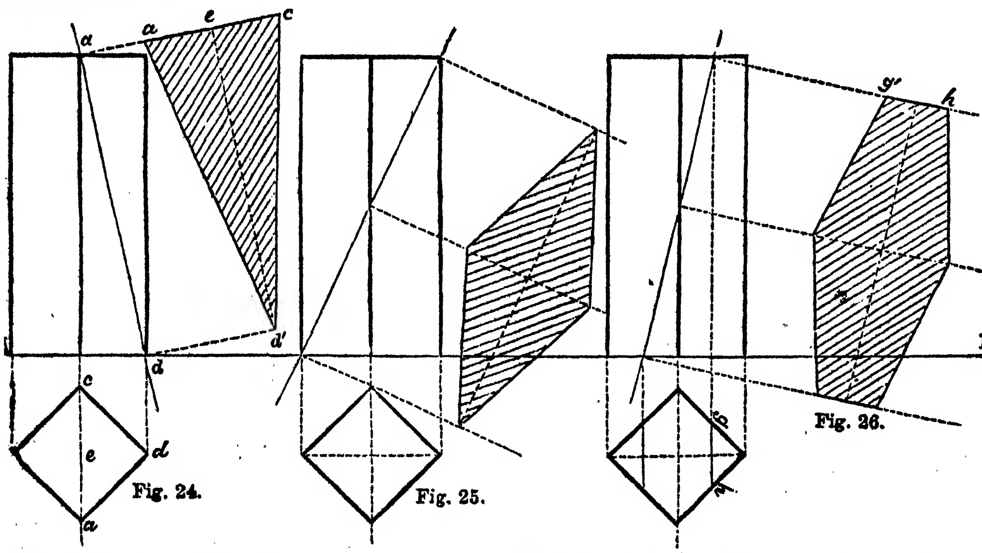


Fig. 24. Fig. 25. Fig. 26.

But although the position of the lines is altered, as far as their relation to the horizontal plane is concerned, they still remain *parallel* to the *vertical* plane; and if the eye were placed immediately over the object, the widths across from the front to the back would be seen to be the same throughout the motion. Therefore, from the angles of the plan of Fig. 21 draw horizontal lines, which will give the widths of the two upper sides; the two under them, being the same, will be hidden by them. The length of the diagonal of the top and bottom, which is at right angles to the vertical plane, thus remains unaltered, but the diagonal which is inclined will necessarily become shortened. This will be seen in continuing the projection of the plan. Draw perpendiculars from the two extremities of the line which is the edge elevation of the end, to cut the middle line of the three horizontals previously drawn in the lower plane. From the middle point of the edge elevation then draw a perpendicular which will cut the *two* outer horizontal lines, and thus four points will be obtained, and these united will give the *losenge*, which is the plan of the *square* end when inclined. (Refer to Fig. 14.) The lower end of the prism will be obtained in a similar manner.

Fig. 23.—It is now required that the object shall be rotated on its solid angle, so that the axis shall be at a *compound* angle —that is, it shall not only be obliquely placed in relation to the horizontal, but to the vertical plane. This operation has been shown in Fig. 5, and it is therefore only necessary to remind the student that, so long as the inclination of a line in relation to the horizontal plane is not altered, no change but that of *position* will occur in the plan; for, however much the object may

be rotated *horizontally*, the length of the space it overhangs will not be extended, nor will the *heights* of any of the points be altered; and this knowledge is the key to the projection of Fig. 23.

Place the plan of Fig. 22 so that its axis and the edges parallel to it are at 45° to the intersecting line, then from each point in the plan raise perpendiculars, and intersect them by horizontals drawn from the corresponding angles in the elevation of Fig. 22. Join the points so obtained, and the result will be the form shown in the upper projection of Fig. 23.

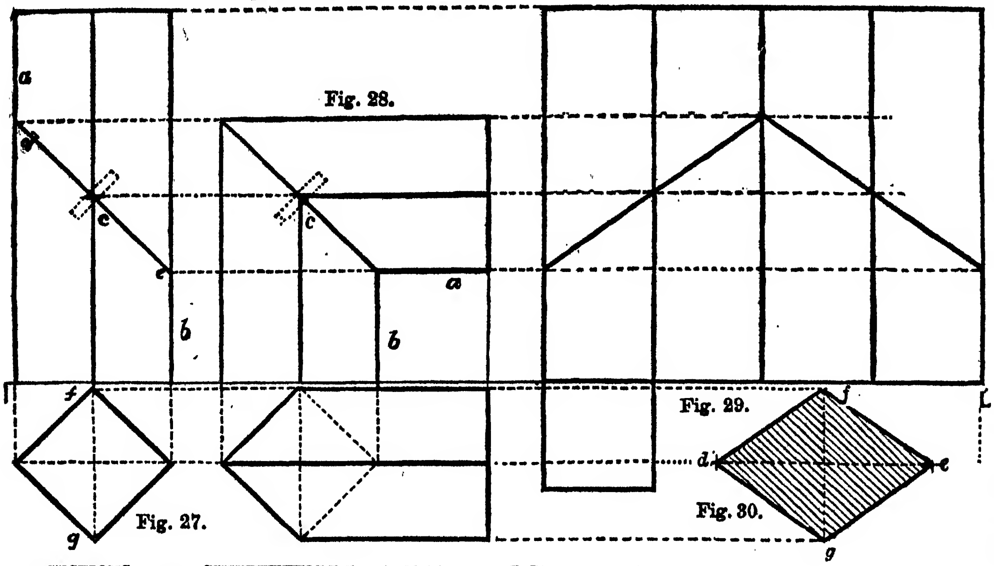


Fig. 27. Fig. 28. Fig. 29. Fig. 30.

SECTIONS.

Fig. 24 is the plan and elevation of the square prism forming the subject of the last exercise. It is required to find the true shape of a section or cutting, caused by a plane passing through the prism in the direction of the line *a d*. This plane of section would cut through the diagonal *a c* of the top, and the angle *d* of the bottom. Draw the dotted lines *a c* and *d d'* at right angles to the line of section, and at any part draw *d' e* parallel to *a d*. Now it will be evident that this will be the greatest length of the section, and that the *width* will be *somewhere* on each side of *e*; but where? How *wide* will the section be? These are questions which the student will do well to ask himself.

Now it is clear that in passing through *a c*, the section-line cuts the object in the widest part; therefore, if the eye be carried down from *a* in the elevation to *a c* in the plan, it will be seen that the real width on each side of the centre *e* is *e a* and *e c*; therefore, if these lengths be set off on each side of *e* in the section-line, and the points joined to *d'*, then *a c d'* will be the true section.

In Fig. 25 the section-plane passes from one angle of the top to the opposite angle of the bottom, cutting through the middle of the two edges. The length will of course be equal to that of the section-line, and the width, *a c*, as in the last figure.

In Fig. 26 the section-plane passes from a line connecting the middle points of two adjacent edges of the top, to a similar line on the two opposite edges of the base. The width of the section at its middle will be equal to the diagonal *a c*, and at the top and bottom it will be equal to *g h*. It is usual to cover sections with lines at 45° to their central line.

Fig. 27 is the plan and elevation of a square prism, similar to that which formed the subject of the last exercise. Now if this be made of wood, and cut so that the section passes through the axis at 45°, and a pin, *c*, be fixed in the centre of the section, at right angles to its surface, the upper portion may be rotated on the pin, so that the short line (*a*) will move to *b*, and be at right angles to it, and the object will be represented by the elevation and plan in Fig. 28.

Fig. 29 is the development, which will show how a metal plate may be cut without waste, so as to make a square pipe to turn a corner, or form an elbow. The true section is shown in Fig. 30, its length being equal to *d e*, and its width to *f g*.

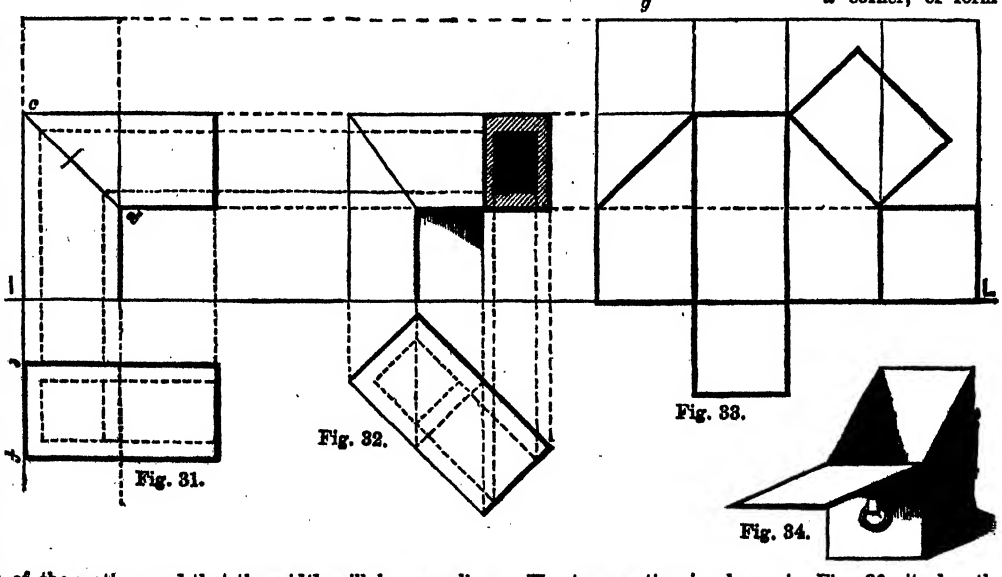


Fig. 31. Fig. 32. Fig. 33. Fig. 34.

Fig. 31 shows the plan and elevation of a piece of a square wooden pipe, when the plane of the section, instead of passing from angle to angle, as in the last figure, passes from side to side, so that the section will be a rectangle, the length of which will be equal to *c d*, and the width to *e f*, instead of a lozenge form, as in the former case.

Here, too, the upper portion may be rotated on a centre, so as to join in a right angle.

Fig. 32 is a projection of the object when placed at an angle to the vertical plane.

Fig. 33 is the development, with the shape of the section attached. It will be seen that this form will give both parts of

the object, the only difference being that in the portion formed by the fine lines the joint or seam will be in one of the edges at the *back*, whilst in the other it will be in the *front*.

Fig. 34 shows how this form is applied in constructing a common sheet-iron coal-scuttle, the lid being the covering of the section.

TECHNICAL EDUCATION AT HOME AND ABROAD.

II.—ON THE ADVANTAGES OF TECHNICAL INSTRUCTION TO WORKMEN.

BY PHILIP MAGNUS.

This change in the conditions of production referred to in the preceding article has wrought a corresponding change in the character of the education which all classes of producers now need. The ability to read, write, and reckon, although the necessary preliminaries of all education, is not sufficient preparation for a skilled artisan. He must know how to draw, and he must also know the elements of science in order that he may understand the applications of science to the trade in which he is engaged. In the workshop of a large factory an apprentice has now little opportunity of obtaining any explanation of the processes he sees being carried on around him, and without this knowledge he has little chance of advancing his own position, or of effecting any improvement in the machinery he uses daily.

At the same time, it is only in the actual workshop that he can be brought under the influence of those various conditions which combine to make an industry successful. Nowhere else can he be made to realise the importance of time as an element of production; nowhere else has he the opportunity of seeing the last and newest machinery in use; and it is only in the actual workshop that he discovers the necessity of precision and accuracy, and is able by contact with other workmen, combining to the same end, to learn the discipline and habits which are essential to the production of good work. But the workshop alone does not afford a sufficient or a complete training to the artisan who is desirous of advancing in his career. It may create an expert workman, who is capable of executing with nicety and precision the particular piece of work on which he may be engaged. In the modern factory in which the separate parts of a machine are turned out in considerable numbers, the division of labour is extended to such a degree that men are employed for years, sometimes for their whole lives, in producing and finishing some element of the machines which hundreds of hands must co-operate to complete; and in this particular branch of work they acquire a mechanical skill that cannot be obtained where work is executed on a less extensive scale, and where the same man cannot consequently be so exclusively occupied on the same task. In the creation of workmen of this sort, technical education avails very little. No amount of previous training can be of much use in producing a workman of this type. When one stands in a great locomotive shop, in a shipbuilding yard, or in works in which weaving-looms or spinning-mules are manufactured in large numbers, and watches the workmen almost automatically engaged in assisting the various labour-saving machines in delivering the metal they have shaped, and when one sees the skill and precision, the result of long practice, with which the man feeds the machine, finishing, adapting, and perfecting its work, one feels that no amount of art training or of science teaching would make that man more capable of performing his allotted task, and that technical education must count for little as compared with muscular strength, constant practice, obedience to orders, sobriety, trustworthiness, and other qualities which education generally helps to inculcate, but which it is not the special object of technical training to cultivate.

Now, it is because we in England have hitherto been successful in supplying with machinery the markets of the world, and in being able to produce machines of the same kind in large numbers, and consequently of employing to a great extent unskilled labour in our works, that manufacturers at home have not been forward in advocating technical education, the want of which has of late years been so generally felt by our artisan population. It cannot be denied that in spite of our deficiency in this respect—in spite of the fact that only now technical schools are being established in London and in all our chief manufacturing towns, whilst for years they have formed a most important feature in the educational machinery of the Continent of Europe—our pre-eminence in the manufacture of stationary and locomotive engines and of all kinds of machines has remained unshaken; and this, notwithstanding the heavy duty that has to be paid on the import into other countries of these goods. And we may be certain that so long as English manufacturers, relying on the natural advantages which England possesses in its iron and coal fields, are able to undersell their foreign competitors in their own or in neutral markets by employing unskilled labour, they will not be found among the advocates of technical education, or will at most afford feeble assistance to those who are endeavouring to promote it. But there can be no doubt that the policy of these manufacturers, who, satisfied with their past, and, may be, present success, have no fears for the future, is short-sighted in the extreme. There are many industries, formerly almost exclusively our own, of which the scientific knowledge and technical skill of the foreigner have enabled him partially to dispossess us, and there are some important branches of trade which, owing to the superior education of our Continental rivals, have developed exclusively abroad, but which might equally well have flourished in our own country. It is a noteworthy fact that whilst manufacturers abroad ascribe the success they have obtained largely to the influence of the excellent schools which they possess, numbers of English manufacturers, when their trade flourishes, speak slightingly of the advantage of technical education, and do not bestir themselves to establish technical schools until they find their market slip away from them through foreign enterprise and foreign skill. In England, many of the technical schools which have recently come into existence owe such support as they have received from manufacturers to the depression of trade, which has seriously affected their profits; and to a similar cause is due the agitation that is now going on in Ireland in favour of technical instruction, and the new interest which the manufacturers themselves are showing in its progress.

A careful inquiry into the conditions of successful production will undoubtedly show the commercial advantages of giving technical education to the ordinary workman employed in large factories, such as have been referred to above. For as competition increases, and facilities of transit place different countries more nearly on a level as regards natural resources, manufacturers have to study more carefully their markets, and to be more intent on adapting their goods to the exact requirements of their customers. Change of fashion often necessitates change of machinery, and the advantage frequently lies with those who are able most readily to avail themselves of some new application of science to the means of production. The rapidity with which new ideas can be assimilated and adopted by the manufacturer tells greatly upon his chance of success; and the introduction of new methods and of new processes often necessitates changes in the character of the work which has to be done by the foremen, overseers, and the ordinary workmen. It is in this ability to pass easily from one kind of work to another that the intelligent and well-instructed artisan is found superior to the uneducated and machine-like workman; and as variety in production and power of adapting new methods are every day becoming more necessary in nearly every kind of manufacture, the quickness of perception which education tends to develop will gradually come to be one of the most valuable characteristics of our labouring population.

There are other advantages in technically educating the ordinary workman which are likely to be, every year, more appreciated. The conditions of production on a large scale, to which reference has been made, and in consequence of which workmen gain a very limited and circumscribed acquaintance with the details of the manufacture in which they are engaged, renders it every day more difficult to select competent foremen from the rank and file of the workmen. The ordinary hands do not get the opportunity of acquiring that general knowledge of various departments of the work in which they are engaged, nor of the structure of the machinery in use, a general knowledge that is essential to the foreman or overlooker. Tact and judgment and power of influencing one's fellows are no longer

sufficient qualifications for the efficient foreman; and hence the advantage from the manufacturer's point of view of educating the workmen with the view of getting from among them the most capable and efficient to act as foremen and overseers. In affording this instruction, the Science and Art classes and Technical classes, to which attention will be drawn later on, are of incalculable benefit to the trade interests of this country; but it will be pointed out that more than this is needed, and that abroad facilities for higher instruction are offered to lads before they enter the works which are either wanting, or exist on a far more restricted scale, in this country.

But this is by no means all that can be said in favour of giving technical instruction to those employed in our large factories. Apart from the general advantages which education confers upon all persons, be their occupation what it may, in enabling them to do their work more satisfactorily, it is well known that many of the improvements that have been effected in the machinery in use have been suggested by workmen engaged on that machinery; and there can be little doubt that the workman who has made himself master of the principles of mechanics, and who in the evening has had the opportunity of discussing with his technical instructor difficulties which have occurred to him during the day, but which he has not had time then to consider, will be far more likely to help in creating new labour-saving appliances than the untrained and uninstructed workman, whose want of education prevents him from understanding the theory and operation of the complicated machines to which he acts as a feeder. And we must remember that improvements are continually being made in machinery which help to cheapen production, and so, really, to benefit the working classes who are the principal consumers. It is only a few years since that a machine for combing wool was invented, which superseded human labour, and recently the combing machine has been so far perfected that it is fed by automata, which do their work with unerring exactness. The history of the substitution of machinery for hand labour in the manufacture of watches is still more interesting, as showing not only the extent to which mechanical appliances can take the place of manual work, but also the loss of trade to England which has resulted to a great extent from the superior education and technical skill of the Americans and Swiss.

But the particular advantages now referred to, which the trade derives from the superior intelligence of the workmen engaged in it, are not unfrequently regarded as sufficient reason for the disfavour with which some manufacturers look upon all schemes for the development of technical education. A new invention, it must be remembered, often involves a considerable outlay of capital in altering and adapting existing machinery, which, although it ultimately increases production and cheapens the articles produced, if the demand is adequate, may lessen the immediate profits of the manufacturer. Satisfied with the trade he is doing, he has no desire to encourage suggestions on the part of his *employés*, but very much prefers that they shall do the work they are paid to do, and nothing more. A master who receives from his foreman or workman a suggestion for a new contrivance, must either adopt it himself, provided after trial it is found to succeed, or allow the inventor to take it elsewhere; and in either case he may be for some time a loser rather than a gainer by the improvement. In the end, all such improvements benefit not only the consumers but also the producers; but there are many persons who cannot see beyond the immediate prospect of loss.

To the intelligent workman the advantages of technical education are unquestionable; for it provides a method of selection by which he is enabled to better his position, and to rise from the ranks to some superior post. Without the opportunities afforded by special instruction, the man of intellect and genius might remain through life on a level with those who are in every way inferior to him. It is quite true that the history of invention shows that many men without these advantages have succeeded in originating and perfecting great works; but education gives to the patient, the steady, and persevering, opportunities of progress, advancement, and distinction which otherwise they could not hope for. By no means the least of the advantages of technical instruction is that it affords a means of educating the workman through the medium of his own trade.

SEATS OF INDUSTRY.—I.

BIRMINGHAM.

BY H. R. FOX BOURNE.

AMONG the seats of modern industry, English and foreign, which in this series of papers will be briefly described, Birmingham is fairly entitled to the first place. "I sell here," Matthew Boulton, Watt's partner in the manufacture of steam-engines, said to Boswell in 1776—"I sell here, sir, what all the world desires to have, *power*." And long before the steam-engine was invented, Birmingham took the lead in the production of the various tools by which other towns have been able to grow as homes of special industries.

Now the busiest hardware town in England, it is also, perhaps, the oldest. Tradition and local antiquities support the belief that it was a place of note—"very eminent for most commodities made of iron," according to the historian Dugdale—even before Britain was a Roman province. Its primitive inhabitants may have made Boadicea's war-chariots, and spears for her warriors; at any rate, they set the fashion of metal-working, which has thriven among their successors ever since. "I came through a pretty street as ever I entered," says Leland, the quaint traveller of Henry VIII.'s reign, "into Birmingham town. There be many smiths in the town, that use to make knives and all manner of cutting tools, and many lorimers that make bits, and a great many nailers, so that a great part of the town is maintained by smiths, who have iron and coal out of Staffordshire." Iron and coal out of Staffordshire have continued to feed the staple trades of Birmingham, and by those trades it has been made more than a hundred times as great as it was in Leland's day. Its growth, however, has been rapid only in recent times. Two centuries ago it had about 5,000 inhabitants, and ninety years ago some 50,000. At the time of the census taken in 1881, the population numbered 400,774, and there cannot now be many less than 412,000 persons crowded into an area little more than two miles long and nearly as broad, and most of them directly connected with the great hardware industries which, having their centres in Birmingham itself, spread over all the adjoining districts and help to supply all the world with steam-engines and pins, pens, guns, and a thousand and one other articles of various sort and use.

Steam-engines rank first. Boulton said truly that in selling them he sold power; and the new power, that has effected a revolution in all manufacturing enterprise, has wrought a wonderful change in the industries of Birmingham. A hundred years ago, when Boulton was a young man, the town was fairly described by Burke as "the toy-shop of Europe." In it swords, nails, and sober implements of many kinds were made and sold; but it was especially famous for its production of trinkets and nicknacks. John Taylor, then its richest and most influential manufacturer, made his fortune out of buttons, buckles, snuff-boxes, ornamental clocks, and other fancy articles. During some years, £800 worth of buttons were turned out of his workshop every week, and one of his workmen earned twelve shillings a day by painting snuff-boxes for a farthing a-piece; while his shop-sweepings, containing quicksilver and scraps of gold, silver, and brass, were sold for £1,000 a year. Boulton carried on the same sort of trade at Snow Hill, then the centre of manufacturing energy in the town, during some years previous to 1762, when he transferred his business to Soho, a miserable village two miles out of the town, where a water-mill had been set up, and he saw an opportunity of carrying on his old trade of toy-making with greater advantage. That he did, and Soho became famous for its manufacture of buckles, buttons, and watch-chains, candlesticks, urns, ormolu wares, and the like. He made in it every variety of "Brummagem goods," trying always to redeem the town from the ill repute which then, even more than now, it had by reason of the trumpery articles which inferior and dishonest manufacturers produced. "The prejudice that Birmingham hath so justly established against itself," he said, "makes every fault conspicuous in all articles that have the least pretensions to taste. How can I expect the public to countenance rubbish from Soho while they can procure sound and perfect work from any other quarter?" Boulton's work was sound and perfect, and he made great profit out of it before it was applied in a new and very notable way in 1774. In that year he entered into part-

nership with James Watt, whose invention of the steam-engine had been lying idle during nine years for want of a shrewd man of business to work out the ideas of the brilliant man of genius. This is not the place for rehearsal of the memorable exploits of Boulton and Watt in manufacturing steam-engines and convincing the world of their value. But the partnership and its results must be noted as forming the chief episode in the industrial history of Birmingham. The first steam-engine was made at Soho in 1775. The Soho Foundry now covers an area of ten acres, and in it, prior to 1866, there had been manufactured 1,878 steam-engines, with a nominal horse-power of 70,958, but able to do more actual work than could be performed by 250,000 horses. Bearing the illustrious title of Boulton and Watt until 1848, the firm conducting this foundry is now known as James Watt and Co. In Soho and its neighbourhood other great establishments for the construction of steam-engines have grown out of the good example of Matthew Boulton, "the father of Birmingham," who may also be claimed as a foster-parent by every one of the hundred towns, in and out of England, which find their profit in engine-making.

The staple industries of Birmingham, however, are concerned rather with the construction of metal and other goods by help of steam-engines than with the manufacture of steam-engines themselves. Among these brass manufactures are the most important. About 90,000 tons of copper are consumed each year in all parts of the world. Of that quantity some 60,000 tons are procured in England, or brought into it, and nearly 20,000 tons go to Birmingham, to be converted into brass by the addition of 11,000 or more tons of zinc. The entire supply of copper and zinc worked up in Birmingham, including old brass re-wrought, in 1865, was nearly 40,000 tons, and its value as raw material about £2,400,000. There were 50 manufacturers of brass and brass goods in the town in 1800. In 1835 the number had risen to 160, and in 1865 to 216. In the latter year about 7,000 men and over 2,000 women were directly engaged in these trades. As they require delicate manipulation, and furnish good wages to all who work at them, their importance to the town is very great.

Another highly-paid calling, closely connected with brass-work, for which Birmingham is famous, is the gun-trade. The story goes that William III., soon after his accession, was complaining that England made no guns, and that he had to send all the way to Holland for them, when Sir Richard Newdigate reminded him that "the men of Birmingham were masters of all that skill and metal could do," and showed him that their guns were at any rate as good as any to be procured abroad. Thereupon the local manufacturers were ordered to make weapons for the English soldiers, and the business has been mainly carried on by their successors ever since. Besides the great Government factories, more than 600 employers are concerned in gun-making and kindred trades. Nearly 4,000 men and boys are engaged in producing the materials, and rather more in setting up and finishing them. Besides the weapons supplied for the English troops, others—good, bad, and indifferent—are made in great numbers for private customers at home and foreigners of every nation.

A more harmless trade connected with brass manufacture, in which Birmingham excels, is pin-making. Pins used to be made much of, as illustrating the value of division of labour, the services of fourteen persons being required for the perfecting of a single pin. Now, however, the whole work is done almost instantaneously by help of an ingenious machine invented in 1824 by an American named Wright. During a single revolution of a wheel the requisite length of brass wire is cut off, pointed at one end, and provided with a head at the other, leaving nothing to be done but the whitening, which is effected by boiling in a copper vessel with tin and bitartrate of potash. One Birmingham house, that of Edelsten and Williams, turns three tons of brass wire into pins each week; and there are twenty other houses devoted to the same trade.

There are also twenty steel-pen manufactories, and most of them much larger than the pin-shops, in Birmingham. The growth of this trade is remarkable. Sixty years ago a steel pen was a curiosity, and, clumsily shaped as it was, could hardly be bought for five shillings. Ten years later the price was about a shilling; but before then Joseph Gillott had embarked in the business, and to him and to Josiah Mason are mainly due the improvements in the manufacture. Steel pens soon came into favour, and their increased use quickly reduced the price. In 1865 the Birmingham makers produced about 100,000 gross every week, and gave employment to nearly 400 men and boys and more than 2,000 women and girls. Unlike pins, pens are still produced by minute division of labour. They pass through at least twelve processes, yet the wholesale value of the commoner sorts is often as low as three-halfpence a gross.

Pins and pens will serve to show how, in Birmingham, the heaping of small things goes to make a great trade. The names of the trades, still justifying Burke's epithet, "the toy-shop of Europe," are legion. Of button-making alone there are still two or three dozen varieties, altogether giving work to about 180 employers and more than 6,000 labourers. The old gold and silver buttons that suited the foppery of last century have gone out of fashion, but their places have been taken by cheaper and more convenient articles. Linen, silk, and velvet buttons, steel, brass, bone, glass, pearl, and wood, are turned out by the million every week. Then there is a large trade in gilt watch-keys and cheap jewellery of every sort, a larger trade in screws and nails, chisels and other tools, and one larger still in fenders and stoves, bedsteads and other ironmongery.

One of the most interesting developments of the old "toy" trades of Birmingham is the manufacture of electro-plated goods. Silver-plating was introduced at Soho by Matthew Boulton more than a hundred years ago, and the rude chemistry of his day made it necessary for the silver coating upon copper to be very solid unless the article produced was in the course of a few weeks to become good for nothing. The modern process of electro-plating was only adopted about forty years ago. In 1838 Messrs. Elkington were employed in coating military and other metal ornaments with gold and silver in the old way, when they, or some chemists in their employ, conceived the plan of depositing costly metals on cheap ones by utilising the decomposing powers of an electric current. Out of their experiments resulted the finished process for which their house is still famous. They have now more than fifty rivals in Birmingham, and the trade, also carried on extensively in Sheffield and elsewhere, has become an important branch of British industry. There is electro-plating in gold as well as in silver, and by it Birmingham is able to give cheap gratification to the vanity of young men and maidens too poor to buy good trinkets. An instance of electro-plating at its cheapest and flimsiest appears in those miniature gilt lockets, supplied with tolerable likenesses of the Prince and Princess of Wales, which a few years ago were sold wholesale for a halfpenny a-piece.

Birmingham has some trades, also, which are not concerned in metal-working. In papier-mâché manufacture, started by Henry Clay, a native of the town, in 1772, it has had almost a monopoly ever since; and it is famous for its dressing-cases and other products of leather-working, its tortoiseshell goods, and the like. Nearly every month, it has been truly said, produces in Birmingham some new invention or some new trade.

The old and the new industries combine to make the town wonderfully prosperous. "The history of every trade and every manufactory," says Mr. Timmins, a competent local authority, "is one of rapid growth. Beginning as a small master, often working in his own house, with his wife and children to help him, the Birmingham workman has become a master, his trade has extended, his buildings have increased. He has used his house as a workshop, has annexed another, has built upon the garden or the yard, and consequently a large number of the manufactories are most irregular in style. Whenever the business has overgrown its early home, and it is necessary to remove or to rebuild, a better class of building is invariably adopted. The warehouses, the workshops, and the offices erected during the last few years, all show not only great attention to physical wants and sanitary laws, but generally some appreciation of ornament and some love of art. Birmingham is, in fact—Sheffield, perhaps, only excepted—the town of all others where social and personal freedom is extreme. The large number of small manufacturers are practically independent of the numerous factors and merchants they supply. The workmen, mostly untrammelled by trades' unions, are paid according to their merits, and skilled labour of all sorts is nearly always in demand. The enormous variety of the trades renders general bad trade almost impossible; for if one branch is slack, another is usually working full or even over time. In no town in England

is comfort more common, or wealth more equally diffused. If millionaires are few, absolute poverty and wretchedness are also rare. Dwellings, however humble, are not overcrowded, as in many large towns, and very rarely is more than one family found in one house." Birmingham is thus, on social grounds as well as on commercial, one of the most interesting of the great seats of English industry.

CHEMISTRY APPLIED TO THE ARTS.—I.

BY GEORGE GLADSTONE, F.C.S.

BLEACHING.

All the fabrics used for clothing and other purposes, which are made of cotton, flax, wool, jute, silk, and such like articles, are more or less coloured when they are first produced. Raw cotton is naturally almost white; but it is liable to be mixed with minute fragments of the husk, and other extraneous substances, besides grease and dirt, which destroy the purity of its character, and render it quite grey by the time it has passed through the spinning-mill and loom. Flax and jute are by nature rather dark-coloured; silk is always yellow; and wool is anything but white when in the fleece. None, therefore, of the goods made from these articles present a clean and inviting aspect when they leave the hands or machine of the weaver.

In order to render them fit for the market, they must not merely be washed, which would only remove the dirt, but they must generally be bleached, or, in other words, made white. Grey calicoes are not bleached, but the tint they possess prevents their being used for a great variety of purposes. If they have to be dyed or printed with patterns, it is still more important that the fabric should be bleached, because otherwise the colours or patterns would appear indistinct and dirty.

The bleaching process is therefore a very important one. It is one, however, that is continually going on without man's interference, of which most housewives find too many instances. We are all familiar with the power of the sunlight in fading carpets, curtains, etc., which are much exposed to its influence. Almost every article that can be named is subject to the same, timber and even stone losing much of their colour by exposure. The effect is increased by occasional showers of rain.

In the early ages man copied the process of Nature, and exposed his manufactures to these influences for the purpose of rendering them white. Water is generally so cheap, and sunlight costs nothing at all, that modern science has not altogether supplanted this plan; but in these days, dispatch is a matter of so much importance that we cannot wait while Dame Nature does her work, and we must therefore either hurry her on, or find some more expeditious method.

About 100 years ago, the attention of chemists was drawn to a substance which is now known to be one of the most common, and at the same time important, chemical elements—chlorine. In combination with sodium, it forms the well-known table-salt (chloride of sodium), and is therefore one of the most widespread substances in Nature. It was not long before its bleaching qualities were discovered, and then commenced a new era in the art of which we are now writing. The best manner of using the chlorine was the subject of many experiments, and improvements have from time to time been suggested; but still chlorine, in one form or another, is the article upon which the bleacher of cotton relies. A great economy, both of time and labour, is the result; the effect which could formerly have been gained only by a vast amount of labour, and an exposure of months to the atmospheric influences, being now attained within an equal number of days.

What is the principle upon which chlorine acts in the bleaching of goods made of vegetable fibres? Let us get at the philosophy of the matter first, and then proceed to the working of it out in actual practice. The chemical process amounts simply to this—to give the chlorine employed the opportunity of entering into combination with the colouring matter in the fabric to be bleached, the result of which is the formation of a white compound which can be readily separated from the manufactured article.

There are, however, many niceties in the operation which need to be borne in mind, in order to produce a satisfactory result. Raw cotton imbibes a certain amount of dirt and grease in the processes of picking, ginning, and sending from the place of growth to the manufacturing district; and in the subsequent processes of spinning into yarn, and of weaving into calico or other fabrics, a good deal more of both these impurities is acquired. It is important to get rid of these, and more particularly the grease, before the goods are subjected to the actual operation of bleaching. The mere dirt is easily removed by the ordinary process of washing, which is therefore one of the first things to be done. Grease or oil is not, however, to be got rid of by this means, and the quantity of these troublesome ingredients when the goods come out of the loom is by no means inconsiderable. The simplest and cheapest way of purifying the fabric from these is to convert them into a soap, by boiling the goods in a solution of lime-water or any alkali. The soap thus formed is easily separated, and the material is then ready to be subjected to the bleaching process. During these preparatory operations, which consist of alternate washings in lime-water, acids, and caustic alkalis, between each of which the fabric is thoroughly rinsed in pure water, the article operated upon loses a good deal of its colour, though the most important have yet to follow.

There are two ways of conducting the succeeding process: the one is by bringing the goods under the influence of chlorine in its free state (either as a gas or dissolved in water), and the other by using the chlorine in combination with a base, such as calcium, of which lime is the oxide. The former is adopted more generally on the Continent, the latter in England. The former is very effective and rapid in its operation, but it involves a certain amount of risk, because the chlorine in that case is liable to do too much, and destroy or burn the fibre itself; the latter is more easily regulated, so that there is less risk of injuring the strength of the calico. Even in this case, it is necessary to adjust with care the strength of the solution of chloride of lime, its temperature, and the time employed; because an increase of temperature, or a prolongation of the time, will operate as prejudicially as an excessive quantity of the bleaching powder. The colouring matter is the first attacked, and as soon as that has been sufficiently acted upon, the fabric should be withdrawn from any further influence.

The chloride of lime is dissolved in a large quantity of water, to make a bath into which the goods are to be placed after it is reduced to such strength as is desired, a point which varies considerably according to the quality and character of the goods to be bleached. Into this solution the cloth is put, and remains there generally for about six hours, by which time the chloride of lime has been taken up. It then passes into a weak bath of sulphuric acid, when the acid attacks the calcium, forming sulphate of calcium, and leaving the chlorine free to act upon the colouring matter. The sulphate is easily removed by steeping in water for eight or ten hours; and the colouring matter, having been already decomposed by the chlorine, is got rid of by boiling for about eight hours in a solution of caustic or carbonate of soda. The goods are finally passed through a bath of weak acid, to prevent the chance of their subsequently turning colour in consequence of any resinous matter remaining behind, and are then dressed and prepared for market.

The time occupied in bleaching cotton goods by the agency of chlorine need not occupy more than two days. It is, however, better to take rather more time, as the most expeditious mode involves the use of rather stronger solutions than are desirable; and a very thorough washing between the various steps of the process is of importance, because otherwise the fabric is liable, in course of time, to turn yellowish and spotty in some places. Care in this respect is all the more important if the goods are intended to be dyed or printed, because the colours are certain to be more or less affected if any of the ingredients used should remain behind, or have entered into combination with the fibre itself. The minute details vary considerably in different establishments, as well as according to the class of goods in hand. The solutions of the alkalis are generally prepared by dissolving a certain weight of the substance in a given quantity of water; but as chloride of lime is very apt to lose its strength by keeping, it is usually tested, by observing in a graduated tube how much is required to neutralise a standard solution of indigo, a test which is found in practice to be sufficiently exact.

The process of bleaching linen is somewhat different from the foregoing, though the same in principle. While cotton goods lose at the outside 10 per cent. of their weight, linens lose at

least 30 per cent. by being bleached. This arises from the large amount of colouring matter in the flax, some of which is even imbibed during the process of retting to which the flax plant is subjected in order to separate the fibre from the husk. The great quantity of colouring and resinous matters which have to be got rid of, render the bleaching of flax a much more tedious process than that of cotton, because they prevent the chloride of lime from penetrating the fibre completely during the short time that it is exposed to the influence of this agent; and many bleachers combine the modern chemical process with the old system of exposure to the elements, which, though longer, saves the repetition of some of the mechanical operations. Upon this plan the process generally occupies from six weeks to two months, though by adopting the artificial expedients it need not occupy more than about one-third of this time.

The animal substances used in the manufacture of clothing cannot be treated in the same way, for were they subjected to the operation adopted in the bleaching of vegetable fibres, the material itself would be so far destroyed as to render the goods comparatively valueless. The most important of these substances are wool and silk. They must be described separately.

Wool, it is well known, contains a very large amount of grease, and this is only very imperfectly removed by the process of scouring to which it is subjected before the wool is made into yarn. As in the case of cotton goods, the first thing to be done is to get rid of the greasy substances, but the alkaline leys used by the bleachers of calico to saponify the fatty matters would destroy the wool itself, so that another means of achieving this end has to be resorted to. The best article for the purpose, and which is therefore commonly used, is a mixture of water and stale urine, into a cold bath of which the wool is placed for about twenty minutes. During this time the carbonate of ammonia, evolved in the decomposition of the urea, combines with the grease, forming a substance which is readily removed by washing. If woollen goods are subjected to this treatment there is some difficulty, however, in getting rid of the disagreeable smell which clings to them, in consequence of which carbonate of soda and soap are generally substituted, though they are not so satisfactory in their action.

Though heat facilitates all the operations of the bleacher, it is necessary to avoid it when dealing with wool, because it would not only injure the fibre, but also make it shrink too much. Even in using cold water, the latter result has to be guarded against by keeping the goods stretched on a frame while passing through the various baths. To effect this with the greatest possible economy of liquid, the baths are fitted with two series of rollers, one near the bottom and the other near the top, and the fabric is drawn tightly over and under the rollers alternately.

Having thus prepared the article for the actual bleaching operation, it is now subjected to the action of sulphur, and not chlorine as in the case of cotton. The object of this treatment is not to remove the colouring matter from the wool, but merely to deprive the substance of its colour. It is applied in the form of sulphurous acid, which is a gas readily soluble in water, and may be used in either of these conditions according to the preference of the operator. Those who employ it in the gaseous state have large chambers provided in which the goods are hung up on wooden rails; the door is then hermetically shut, and the burning sulphur is introduced through an aperture in the floor, which is at once closed. In this way the air that is in the chamber becomes thoroughly impregnated with the gas, and the cloth, after an exposure of about twenty-four hours, is completely bleached. An immersion of four hours in water saturated with the gas is sufficient to produce the same result. The aqueous solution may easily be prepared by heating a mixture of sulphate of iron and sulphur in a retort connected by a pipe with the bath, so that the gas evolved should pass into the water, and be absorbed by it until thoroughly saturated, or until a sufficient strength be attained.

The process of bleaching silk is much simpler. In fact, except for special purposes, it can hardly be said to be actually bleached. The very pale tint to which it is usually reduced is attained by repeated boilings in water with soap, then immersion in a bath in which a little carbonate of soda is dissolved, and finally a short exposure to the action of a weak acid, the silk being well rinsed between each operation. A further decolorisation is, however, necessary, if the silk is subsequently to be dyed of a very delicate colour, in which case a weak solution of sulphurous acid is used. Much care has to be exercised throughout, lest the fibre should be affected, which would not only destroy its strength, but also deprive it of the brilliance which adds so much to its value.

The manufacture of the chloride of lime which is now the great agent in the bleaching of goods made of vegetable fibres, is a separate trade, and is principally carried on at the large chemical works in the neighbourhood of Glasgow, Newcastle, and Liverpool.

Machinery is used wherever practicable, in order to economise the cost of labour, and also time. The dash wheel, as it is called, is a most useful and simple contrivance, and one in almost constant requisition, being used in the frequent washings above described. It consists of a large cylinder or drum, divided lengthwise into four compartments, with a large aperture in the end of each, through which two or more pieces of cloth are inserted; water is then added, and connection being made with the steam-engine, the cylinder revolves rapidly, and the motion thus given to the pieces of cloth inside washes them thoroughly in less than ten minutes.

TECHNICAL DRAWING—III.

LINEAR DRAWING IN PARALLEL LINES—FREE-HAND DRAWING.

We now proceed to give another example for practice in drawing parallel lines.

Fig. 6 is the plan and Fig. 7 is the sectional elevation of a platform in which the longitudinal sleepers, *b b b*, rest directly on the ground, and are kept in their places by the cross-sleepers, *a a a a a a*, which rest upon them. These are notched down, so that only half their thickness stands above the longitudinal sleepers. The spaces between these having been duly flushed up as in the previous example, the planking, *c c c c*, is placed *between* the cross-sleepers, of a thickness equal to the portion of their thickness which stands above the longitudinal timbers, the upper faces of the cross-sleepers themselves thus covering a portion of the surface of the platform.

To draw these figures, draw a line at A B, for the ends of the longitudinal sleepers; mark off the widths of these and of the spaces between them.

Now, knowing that the elevation is to be projected from the plan, you may as well carry on the process at the same time that you are drawing the first figure; therefore, at the proper distance, draw the ground-line of the elevation, C D (Fig. 7), and as you draw the longitudinal sleepers, carry down the lines which will give you the ends or sections of the timbers lettered *b b* in the elevation.

Returning to the plan, draw the cross-sleepers, *a a a a a a*, and the lines parallel to the longitudinal sleepers (not shown in the example) which bound the ends of the cross-sleepers, carried up, will give also the ends of the same timbers, and of the planking, in both plan and elevation. It will be seen that the portion of the cross-sleeper which is notched down on to the longitudinal timbers is represented by the width at *a* in the sectional elevation.

The section of the wall may, of course, now be drawn either to pattern, or may be worked to represent brickwork from either of the footings of walls which will be given in the lessons on Building Construction.

These drawings may now be coloured to represent fir, the colour usually employed for this purpose being raw sienna. This should be washed thinly over *all* the wood-work, and when dry the lower sleepers should be covered with sepia, the shadows cast by the upper on the lower timbers to be subsequently added with colour rather darker. When all the colouring is dry, the lines representing the graining are to be freely, but not too heavily, executed with this last darker shade of sepia; and it must be borne in mind that the graining is but secondary, and must not be over-done, and that in the example the lines are engraved closely in order to darken the lower timbers, so that the cross-sleepers may be more plainly visible; but in your drawing you attain this end by the wash of sepia, and therefore you are not required to shade your work in lines. In the ends of the sleepers shown in Fig. 7 it is, however, necessary to draw lines at 45°, in order to show that they are meant to represent sections.

Fig. 8 is the plan and Fig. 9 is the sectional elevation of the planking for the foundations of walls meeting at right angles. This plan, taken from an excellent German example, is such as might be applied in a case where it might not be necessary that the whole of the area should be planked.

To draw this example, draw the line A B (Fig. 8), and B C at right angles to it.

On B C mark off the widths of the lower sleepers and the spaces between them, and from these points draw the lines required for the timbers.

On A B mark off the widths of the upper sleepers and the spaces between them.

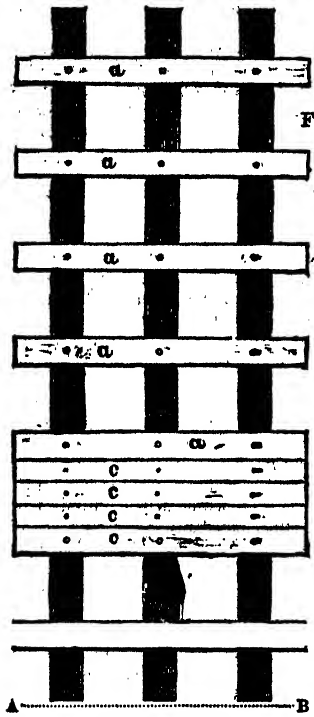


Fig. 6.

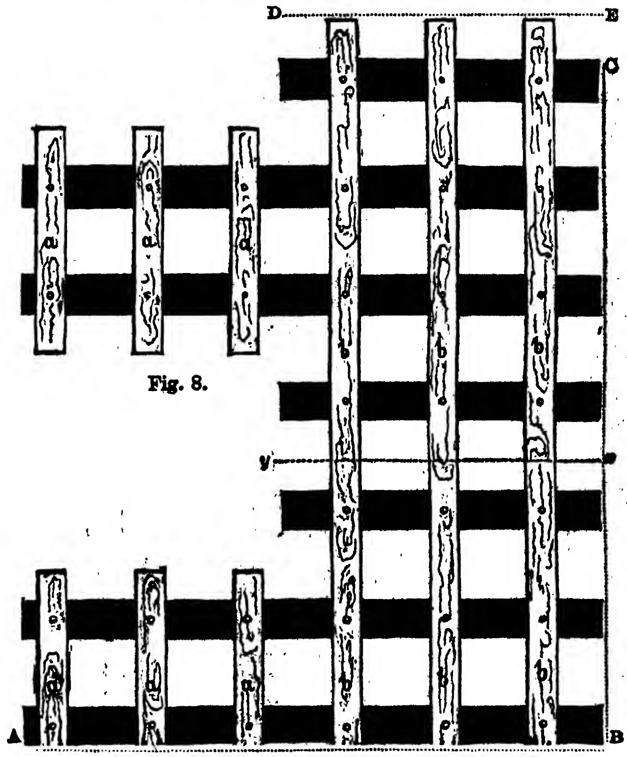


Fig. 8.

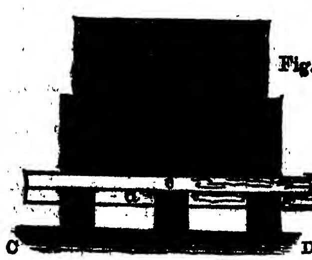


Fig. 7.

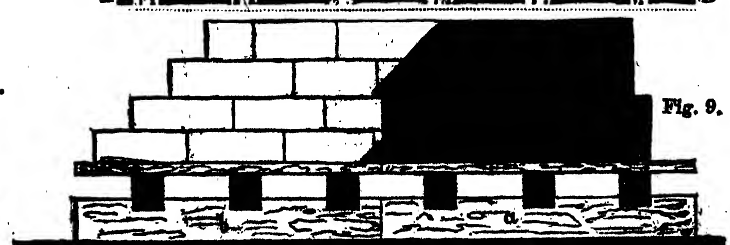


Fig. 9.

Although only three of these are continuous, it is advisable to draw all in pencil as if they were so, which ensures the distant set being immediately opposite to those in the front; and this mode of working is decidedly the more rapid.

It has been mentioned that it is desirable to draw all pencil lines longer than they will be required. We will now inquire why it is so.

Let us suppose the whole plan finished, as far as the pencilling is concerned, and that the next process is that of inking.

Now, of course, you know that the bevelled edge of your rule must be turned *downward*, in order to raise the edge so that the ink from the ruling-pen may not drag against it. This edge, however, obstructs, in a degree, your view of the lines you are to ink, and you either draw your pen past the angles of them or do not rule quite up to them. In either case the result is disagreeable, for you have either to scratch out the superfluous ends or to patch the line, which is exceedingly difficult to do neatly. But if you have drawn out the pencil-lines forming the edges of the sleepers, you at once see the exact length you are to ink; and this same result in inking the long lines will be attained by the pencil-line previously drawn at D E.

You are further advised never to scratch out any extraneous line until *after* you have coloured, and the drawing has thoroughly dried, as otherwise the colour will run into the roughened paper and cause a blotched appearance.

The sectional elevation (Fig. 9) can now be projected from the plan in the manner already explained. The shadow cast by the wall (which is a section on the line *y x*) is to be washed in with sepia. Be careful not to mix your colour too thick. Rather repeat the wash in order to darken it.

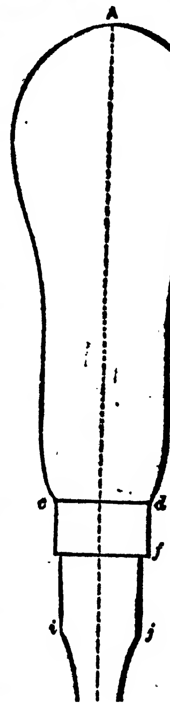
The lines for the courses of stones should be drawn after the colouring and shadowing, so that they may not be washed away.

OF FREEHAND DRAWING.

At this stage it is advisable that the student should be informed that *all* the drawing which is necessary for the artisan cannot be done with *rules and compasses*, but that some portion of the work must be drawn by "freehand."

It is important that a workman should be able, with his piece of chalk or pencil, to sketch roughly, by hand, the form of any object he is required to make, or that, visiting any exhibition or foreign country, he should be able to bring away with him drawings, however roughly done, of any tool, appliance, useful or ornamental article which may have attracted his attention.

Again, as the examples contained in this or any other work of a similar character advance, it will be seen that curved lines are of constant occurrence; and although some of them, which may be composed of arcs of circles, may be done with compasses, and others may be inked by means of the French curve, there are many which cannot be executed by any other means than by freehand, and there will occur little pieces of curved lines continuous with straight ones, which can always be more neatly joined by hand than by instruments, or which a certain amount of practice will enable the draughtsman to execute with his pen or pencil in less time than it would take him to find the centres. But this is not all. The study and practice of freehand drawing gives accuracy to the eye and refines the perceptive faculties; it enables a man to raise his ideas beyond mere straight lines, to cultivate his taste, and in many ways to add beauty to utility.



To the joiner these remarks apply with even greater force than to the carpenter, for there is so much in his work that requires taste and refinement, that to him hand-drawing and a proper cultivation of taste are absolutely indispensable. The Germans (amongst whom technical education has from early times been well attended to) imply this in the very names they give to the different departments of the workers in wood. They do not seem to consider the work of the house-carpenter to be merely making a good joint or planing wood very skilfully, and therefore do not use the term "joiner." They call the workman "Bau-tischler" (the *building*, *cabinet*, or *table maker*), and the "Fein-zimmermann" (the *fine-room man*); and these terms will at once be understood as conveying the meaning that from the joiner not only neatness but taste is required; and he cannot acquire this, or even cultivate that which may be (and in many cases *is*) natural to him, without patiently studying and practising the delineation of beautiful forms which Nature spreads so bountifully around, and which men of former periods have produced. The South Kensington Museum, a perfect art-world, contains innumerable specimens of the application of art to trade purposes, and the student is strongly urged to avail himself of the advantages of such an exhibition, and of the excellent tuition given in the numerous schools of science and art, spread not only over London, but throughout the provinces.

The object of introducing freehand drawing at this stage is that the student may practise it, little by little, as he progresses with his linear drawing, and so cultivate both branches equally. This will be found more satisfactory than allowing the study of ruling-work to outstrip hand-work; for, where this is the case, whilst the ruled lines may be exceedingly well done, the curved parts will be so clumsily added that the appearance of the drawing will be quite spoiled.

It is intended to introduce at a further stage the elements of ornamental forms; but in commencing, it is deemed best that the subjects should be such as are well known to the student. He will then be able to check his own work, for he will at once see whether his drawing is really like the tool he has in his basket; and I would hope that it may lead him to try to make drawings of others direct from the objects and unaided by copies.

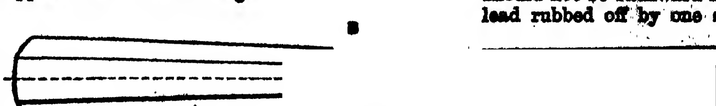


Fig. 11.

We commence, then, with Fig. 10, which is intended to represent a joiner's screwdriver; and this example, simple as it is, will afford excellent practice in a most important branch of the study—the balancing of parts.

Here the perpendicular, A B, is to be drawn first, and, when this is accomplished (by *hand*, not by means of the rule), proceed in the following manner:—

Draw the lines *c d* and *e f*, crossing A B at right angles; observing, but *not* measuring, the distance between them. Next draw the line *g h*, which is to form the edge of the blade; and also dot fine lines across at *i j* and *k l*.

All these lines are, in the first instance, to be drawn of indefinite length.

The two points to be observed are—

1. That they are at the proper distances apart.
2. That they are all really at right angles to A B.

Now mark off on each side of the central perpendicular the length of half the diameter of the brass ring, and draw the lines *c e* and *d f*.

The handle is to be drawn next, and this is formed of a continuous curve. Begin at A, and in the lightest manner possible sketch the curve extending to *c*. Adopt as a constant rule, that when two curves are to be balanced, it is advisable to draw the *left* side first, for if the right side were drawn before the other, you would most likely cover it with your hand whilst sketching the left; this would, of course, render your getting your two sides alike very difficult.

When, then, you feel in some degree satisfied that the left side of the handle is nearly correct, add the curve from A to *d*.

Observe.—There must not be a sharp point at A. The two sides must merge smoothly into each other at the top, so as to form one complete curve.

You can well imagine how very absurd a screwdriver would appear, and how very unfit it would be for work, if it had a sharp point at the top of the handle.

Now commence the blade, by drawing the perpendiculars *e i* and *f j*; then the curve *i k* on the left side, and *j l* on the right.

Mark off on *g h*, on each side of the perpendicular, half the width of the edge of the blade, and then draw the lines *kh* and *lg*, which will complete the form.

Now this will constitute the rough sketch. The next step is to convert it into a *drawing*. Pass your india-rubber lightly over the pencil lines, so as to remove as much lead as possible, without entirely erasing the form.

Fig. 11 is a sketch of a carpenter's chisel.

In beginning this, draw the central horizontal line, and across this draw the lines for the edge of the chisel, and the upper and lower ends of the handle.

Next draw the sides of the blade, which, differing from those of the screwdriver, are parallel to the central line. The lines for the edges of the handle are not, however, parallel, as the handle is wider at the upper than at the lower end.

Observe.—In using india-rubber, it is better to rub in the *direction of the lines* rather than *across* them; and when there is much lead upon the paper, it is better that the friction should be rapid and light rather than slow and hard. The rubbing should not be backward and forward, by which the lead rubbed off by one stroke is rubbed on again by the next; but the action should be like planing or filing—viz., in one direction, the rubber being raised in the backward motion.

The paper should at this stage present a perfectly clean appearance, with a very clear but slight trace of the form.

Now, with a fine, cleanly-cut point to your pencil, trace over the outline, avoiding all raggedness, and endeavouring to get each line of the same thickness throughout; those on the right side are to be rendered a little darker than the others. This process is called "lining in."

By following these directions closely, which are similar to those given for outline-work in the earlier "Lessons in Drawing" in THE POPULAR EDUCATOR, and taking an example for practice from any tool that he may be in the constant habit of using, the beginner will soon find himself able to produce creditable drawings.

PRINCIPLES OF DESIGN.—I.

By Christopher Dresser, Ph.D., F.L.S., etc.

INTRODUCTION—VALUE OF ART-KNOWLEDGE—MEANING CONVEYED BY ANCIENT ORNAMENTATION.

At the very commencement of this series of articles on Ornamental Design, which I have undertaken to write at the request of the Editor of The Technical Educator, I desire to say that I address myself especially to working men, and that my sole object will be to teach what I consider useful to them. There are many handicrafts in which a knowledge of the true principles of ornamentation is almost essential to success and there are few in which a knowledge of decorative laws cannot be utilised. The man who can form a bowl or a vase well is an artist, and so is the man who can make a beautiful chair or table. These are truths; but the converse of these facts is also true; for if a man be not an artist he cannot form an elegant bowl, nor make a beautiful chair.

At the very outset we must recognise the fact that the beautiful has a commercial or money value. We may even say that art may lend to an object a value greater than that of the material of which it consists, even when the object be formed of precious matter, as of rare marbles, scarce woods, or silver, or gold.

This being the case, it follows that the workman who can endow his productions with those qualities or beauties which give value to his works, must be more useful to his employer than the man who produces objects devoid of such beauty, and his time must be of higher value than that of his less skilful companion. If a man, who has been born and brought up as a "son of toil," has that laudable ambition which causes him to seek to rise above his fellows by fairly becoming their superior, I would say to him that I know of no means of his so readily doing so, as by his acquainting himself with the laws of beauty, and studying till he learns to perceive the difference between the beautiful and the ugly, the graceful and the deformed, the refined and the coarse. To perceive delicate beauties is not by any means an easy task to those who have not devoted themselves to the consideration of the beautiful for a long period of time, and of this be assured, that what now appears to you to be beautiful, you will shortly regard as less so, and what now fails to attract you, will ultimately become charming to your eye. In your study of the beautiful, do not be led away by the false judgment of ignorant persons who may suppose themselves possessed of good taste. It is very common to assume that women have better taste than men, and some women seem to consider themselves the possessors of even authoritative taste from which there can be no appeal. This may be the case, only we must be pardoned for not accepting such authority, : should there be any over-estimation of the accuracy of this gc taste, serious loss of progress in art-judgment might result.

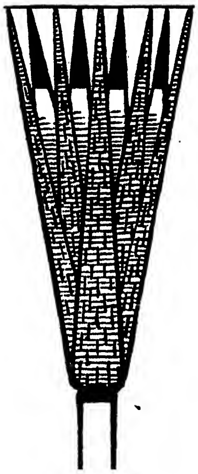
It may be taken as an invariable truth that knowledge, a knowledge alone, can enable us to form an accurate judgme respecting the beauty or want of beauty of an object, and who has the greater knowledge of art can judge best of t ornamental qualities of an object. He who would judge righ of art-works must have knowledge. Let him apply himse then, to earnest study, for thereby he shall have wisdom, a by his wise reasonings he shall be led to perceive beauty, a thus have opened to hir new source of pleasure.

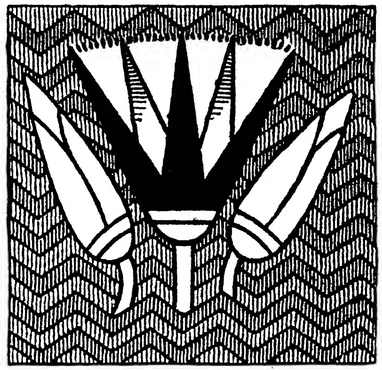
Art-knowledge is of va to the individual and to country at large. To individual it is riches a wealth, and to the natior saves impoverishment. Ta for example, clay as a na ral material: in the ha of one man this mate becomes flower-pots, wo eighteen-pence a "cast" number varying from si to twelve according to si in the hands of anothe becomes a tazza, or a v worth five pounds, or p haps fifty. It is the which gives the value, not the material. To nation it saves impover ment.

A wise policy indu a country to draw to it all the wealth that it without parting with m of its natural material t is absolutely necessary. for every pound of clay t a nation parts with, it draw to itself that amour gold which we value at pounds sterling, it is viously better thus to with but little material yet secure wealth, than to part with the mat either in its native co tion, or worked into co vessels, at a low rate, tl by rendering a great poverishment of the na resources of the cou necessary in order to wealth.

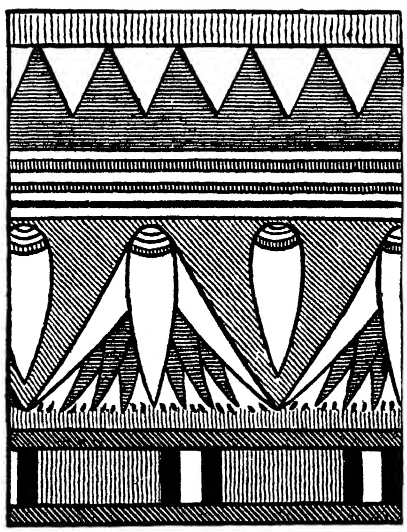
Men of the lowest de of intelligence can dig iron, or copper, or qu stone; but these mate if bearing the impres mind, are ennobled and dered valuable, and the strongly the materia marked with this enno impress the more valuable it becomes.

I must qualify my last statement, for there are possible in which the impress of mind may degrade rather than e and take from rather than enhance, the value of a mat To ennoble, the mind must be noble; if debased, it can debase. Let the mind be refined and pure, and the more it impresses itself upon a material, the more lovely doe material become, for thereby it has received the impre refinement and purity; but if the mind be debased and im the more does the matter to which its nature is transm become degraded. Let me have a simple mass of clay candle-holder rather than the earthen candlestick which





A



B

FIG. 1.—THE LOTUS (BLUE WATER-LILY) OF THE EGYPTIANS, AS CONVENTIONALLY TREATED BY THEM.

A. Open flower and bud on mummy-case. B. Flower and bud on border or cornice. C. Lotus flower and stalk.

presents such a form as is the natural outgoing of a degraded mind.

There is another reason why the material of which beautiful objects are formed should be of little intrinsic value, besides that arising out of a consideration of the exhaustion of the country, and this leads me to say that it is desirable in all cases to form beautiful objects of an inexpensive material as far as possible. Clay, wood, iron, stone, and copper are materials which may well be fashioned into beautiful forms; but beware of silver, and of gold, and of precious stones. The most fragile material often endures for a long period of time, while the almost incorrosible silver and gold rarely escape the ruthless hand of the destroyer. "Beautiful though gold and silver are, and worthy, even though they were the commonest of things, to be fashioned into the most exquisite devices, their money value makes them a perilous material for works of art. How many of the choicest relics of antiquity are lost to us, because they tempted the thief to steal them, and then to hide his theft by melting them! How many unique designs in gold and silver have the vicissitudes of war reduced in fierce haste into money-changers' nuggets! Where are Benvenuto Cellini's vases, Lorenzo Ghiberti's cups, or the silver lamps of Ghirlandajo? Gone almost as completely as Aaron's golden pot of manna, of which, for another reason than that which kept St. Paul silent, 'we cannot now speak particularly.' Nor is it only because this is a world 'where thieves break through and steal' that the fine gold becomes dim and the silver perishes. This, too, is a world where 'love is strong as death;' and what has not love—love of family, love of brother, love of child, love of lover—prompted man and woman to do with the costliest things, when they could be exchanged as mere bullion for the lives of those who were beloved?"* Workman! it is fortunate for us that the best vehicles for art are the least costly materials.

Having made these general remarks, I may explain to my readers what I am about to attempt in the series of papers which I have now commenced. My primary object will be the bringing about refinement of mind in all who may accompany me through my studies, so that they may individually be enabled to judge correctly of the nature of any decorated object, and enjoy its beauties—should it present any—and detect its faults, if such be present. This refinement I shall attempt to bring about by presenting to the mind considerations which it must digest and assimilate, so that its new formations, if I may thus speak, may be of knowledge. We shall carefully consider certain general principles, which are either common to all fine arts or govern the production or arrangement of ornamental forms. Then we shall notice the laws which regulate the combination of colours, and the application of colours to objects; after which we shall review our various art manufactures, and consider art as associated with the industrial arts. We shall thus be led to consider art furniture, earthenware, table and window glass, wall decorations, carpets, floor-cloths, window-hangings, dress fabrics, works in silver and gold, jewellery, hardware, and whatever is a combination of art with manufacture. I shall address myself, then, to the carpenter, the cabinet-maker, potter, glass-blower, paper-stainer, weaver and dyer, silversmith, jeweller, blacksmith, gas-finisher, mason, designer, and all who are in any way engaged in the production of art objects.

But before we commence our regular work, let me say that without laborious study no satisfactory progress can be made. Labour is the means whereby we raise ourselves above our fellows; labour is the means by which we arrive at affluence. Think not that there is a royal road to success—the road is through toil. Deceive not yourself with the idea that you are born a genius, that you were born an artist. If you are endowed with a love for art, remember that it is by labour alone that you can get that knowledge which will enable you to present your art ideas in a manner acceptable to refined and educated people. Be content, then, to labour. In the case of an individual, success appears to me to depend upon the time which he devotes to the study of that which he desires to master. One man works six hours a day; another works eighteen. One has three days in one; and what is the natural result? Simply this—that the one who works the eighteen hours progresses with three times the rapidity of the one who only works six hours. It is true that individuals differ in mental capacity, but my experience has led me to believe that those who work the hardest almost invariably succeed best.

While I write, I have in my mind's eye one or two on whom Nature appeared to have lavishly bestowed art gifts; yet these have made but little progress in life. I see, as it were, before me others who were less gifted by Nature, but who industriously persevered in their studies, and were content to labour for success; and these have achieved positions which the natural genius has failed even to approach. Workman! I am a worker, and a believer in the efficacy of work.

We will commence our systematic course by observing that good ornament, good decorations of any character, have qualities which appeal to the educated, but are silent to the ignorant, and that these qualities make utterance of interesting facts; but before we can rightly understand what I may term the hidden utterance of ornament, we must inquire into the general revelation which the ornament of any particular people, or of any historic age, makes to us, and also the utterances of individual forms.

As an illustration of my meaning, let us take the ornament produced by the Egyptians. In order to see this it may be necessary that we visit a museum—say the British Museum—where we search out the mummy-cases; but as most provincial museums boast one or more mummy-cases, we are almost certain to find in the leading county towns illustrations that will serve our present purpose. On a mummy-case you may find a singular ornament, which is a conventional drawing of the Egyptian lotus, or blue water-lily* (see Fig. 1), and in all probability you will find this ornamental device repeated over and over again on the one mummy-case. Notice this peculiarity of the drawing of this lotus—a peculiarity common to Egyptian ornaments—that there is a severity, a rigidity of line, a sort of sternness about it. This rigidity or severity of drawing is a great peculiarity or characteristic of Egyptian drawing. But mark! with this severity there is always coupled an amount of dignity, and in some cases this dignity is very apparent. Length of line, firmness of drawing, severity of form, and subtlety of curve, are the great characteristics of Egyptian ornamentation.

What does all this express? It expresses the character of the people who created the ornaments. The ornaments of the ancient Egyptians were all ordered by the priesthood, amongst whom the learning of these people was stored. The priests were the dictators to the people not only of religion, but of the forms which their ornaments were to assume. Mark, then, the expression of the severity of character and dignified bearing of the priesthood: in the very drawing of a simple flower we have presented to us the character of the men who brought about its production. But this is only what we are in the constant habit of witnessing. A man of knowledge writes with power and force; while the man of wavering opinions writes timidly and with feebleness. The force of the one character (which character has been made forcible by knowledge) or the weakness of the other is manifested by his written words. So it is with ornaments: power or feebleness of character is manifest by the forms produced.

The Egyptians were a severe people: they were hard task-masters. When a great work had to be performed, a number of slaves were selected for the work, and a portion of food allotted to each, which was to last till the work was completed; and if the work was not finished when the food was consumed, the slaves perished. We do not wonder at the severity of Egyptian drawing. But they were a noble people—noble in knowledge of the arts, noble in the erection of vast and massive buildings, noble in the greatness of their power. Hence we have nobility of drawing—power and dignity mingled with severity in every ornamental form which they produced.

We have thus noticed the general utterance or expression of Egyptian drawing; but what specific communication does this particular lotus make? Most of the ornaments of the Egyptians—whether the adornments of sarcophagi, of water-vessels, or mere charms to be worn pendent from the neck—were symbols of some truth or dogma inculcated by the priests. Hence Egyptian ornament is said to be symbolic.

* From a lecture by the late Professor George Wilson, of Edinburgh.

* This can be seen growing in the water-tanks in the Kew Gardens' conservatories and in the Crystal Palace at Sydenham.

The fertility of the Nile valley was chiefly due to the river annually overflowing its banks. In spreading over the land, the water carried with it a quantity of rich alluvial earth, which gave fecundity to the country on which it was deposited. When the water which had overspread the surrounding land had nearly subsided, the corn which was to produce the harvest was set by being cast upon the retiring water, through which it sank into the rich alluvial earth. The water being now well-nigh within the river-banks, the first flower that sprang up was the lotus. This flower was to the Egyptians the harbinger of coming plenty, for it symbolised the springing forth of the wheat. It was the first flower of spring, or their primrose (first rose). The priesthood, perceiving the interest with which this flower was viewed, and the watchfulness manifested for its appearance, taught that in it abode a god, and that it must be worshipped. The acknowledgment of this flower as a fit and primary object of worship caused it to be delineated on the mummy-cases and sarcophagi, and on all sacred edifices.

We shall have frequent occasion, while considering decorative art, to notice symbolic forms; but we must not forget the fact that all good ornaments make utterance. Let us in all cases, when beholding them, give ear to their teachings!

ELECTRICAL ENGINEERING.—II.

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INTRODUCTORY (*continued*).

WITH the science of electricity in the condition described in the first chapter, many attempts were made to utilise its properties for conveying signals from place to place; in other words, for conveying messages by means of *telegraphy*. It was possible to send a current along the metal line joining any two stations, but the difficulty which was experienced was to devise some apparatus by means of which the signal sent at one station could be translated into an intelligible form at the other. This is now done by means of electro-magnetism; but the connecting link between the electric current and the magnet had not been discovered at that time, and the principle of the electrolysis of water appeared to be the most suitable method for attaining the desired object. The two stations were connected by means of twenty-six wires, the ends of which dipped into separate vessels containing acidulated water. If an electric current was sent along any one of these wires it decomposed the water in the cup into which that wire dipped, and a quantity of gas was consequently evolved from that cup. If each of these cups represented a letter of the alphabet, it is clear that by sending currents along the proper wires, in the proper order, a word could be spelt and signalled between the stations. By this means a message could be transmitted from one place to another by utilising the properties of the current as they were then understood. This process was necessarily slow and extremely uncertain, and it can easily be seen why this system of transmitting messages never became popular. The apparatus was costly, and the distance which a current, sufficiently strong to decompose water, could be sent was limited. Telegraphy under these circumstances was not to be thought of, and before any simplifications could be introduced to reduce its expense, the discovery of electro-magnetism provided a less costly, more rapid, and less complicated means for doing the same thing in a much more satisfactory manner. The above method is due to Sömmering, of Munich, and was proposed by him about 1811.

Some connection had long been supposed to exist between electricity and magnetism, and though many experimenters had searched for the connecting link between them, it was not till the year 1819 that it was discovered by Œrsted, of Copenhagen. He took a magnetic needle, and delicately pivoted it so that it took up a position pointing north and south. He then took a wire through which a current could be sent from a Voltaic cell, and held it directly above the needle in the direction of its length. On starting a current in this wire the needle was immediately deflected from the position it originally occupied, and turned through a certain angle depending upon the strength of the current, and it retained this position as long as the current flowed in the wire. If the wire had been placed immediately beneath the needle instead of above it, and the current sent in the same direction, the deflection would have been to the opposite side; but if, while the wire was in this position the direction of the current had been reversed, the deflection of the needle would have been the same as in the first case. Combining these results it is clear that if a wire through which a current is flowing is carried above the needle, and then bent so as to pass back beneath it, both portions of the wire will tend to make the needle deflect in the same direction, and this tendency will be double that which either portion of the wire alone would exert. This principle was carried a step farther by Schweigger, who wound a wire into the form of a coil and placed the pivoted needle at its centre. The force of the current on the needle was thus multiplied by the number of times which the wire was made to pass round the needle; *i.e.*, by the number of convolutions of the wire in the coil. This instrument is known as *Schweigger's multiplier*. This experiment clearly showed that some force, due to the existence of a current in the wire, was acting on the needle, and endeavouring to make it take up a position at right angles to the direction of the wire. This instrument of Schweigger's provided the first simple means for measuring the strength of a current, and was the embryo form of the galvanometer. Œrsted's discovery provided the long-sought-for link connecting the piece of amber which, when rubbed, attracted light bodies, and the magnet or lodestone which attracted the piece of iron. Up to this time these two facts had been widely known, and to Œrsted belongs the honour of having bridged the gap which separated them for a period of more than two thousand years. Now for the first time we have a simple way of translating messages sent along a wire in the form of an electric current from one place to another. Let us suppose that we have one of Schweigger's multipliers at one end of a line joining two places. If a current is sent along that line and passed through the multiplier, it will deflect the needle in a certain direction, and if the current is passed through in the opposite way, the needle will deflect in the other direction. It now only remains to make up a code in which combinations of the deflections of the needle one way and the other, shall represent particular letters of the alphabet, and we have a ready means of spelling out the words in accordance with this code, and of transmitting messages which shall be intelligible at the receiving station. The apparatus required for this system is inexpensive and simple when compared with that required for doing the same work by means of electrolysis, and the rapidity with which messages can be sent by a skilled operator is very much greater. A speed of forty words per minute can easily be obtained on a land-line by means of the hand, while a speed of four hundred or even five hundred words per minute is not considered high if the message is sent automatically. The distance which a message can be sent is practically unlimited, and a single line is all that is necessary to connect the two stations; in fact, two, four, or more messages can be sent along the same line in both directions at the same time by the apparatus which is now in use, without in any way interfering with one another; and what is more surprising still, these telegraph lines can also be utilised for conveying telephonic messages. Without any further great discoveries in electricity, telegraphy in a commercial form was undoubtedly possible, but it is equally certain that it never could have attained the prominent position which it now holds, had it not been for the discovery which almost immediately followed the one which has rendered Œrsted's name famous; this was a rapid and easy method for magnetising iron.

The first suggestion for utilising Œrsted's discovery for telegraphic purposes appears to have been made by Ampère in 1820. He proposed to use twenty-four pivoted needles, which were to be acted upon and deflected by twenty-four currents, each requiring a separate conducting wire. In 1833 Baron Schilling, in Russia, constructed a piece of apparatus in which the deflections of a single needle served to translate a message. Steinheil, of Munich, seems to have been the first to construct a code or telegraphic alphabet, in which each letter is represented by some combination of two elementary signals, and in 1837 he pointed out the important fact that it is unnecessary to use two wires to convey signals; a single wire connected to the earth at both ends answers quite as well. He also

invented a method of printing the message sent on a strip of paper, and to him is due the establishment of the first telegraphic system of communication on the Continent, while Morse in America, and Wheatstone and Cooke in England, must be regarded as the pioneers of commercial telegraphy in their respective countries. The name of Sir William Thomson in connection with submarine telegraphy cannot be overlooked.

Many attempts had previously been made to magnetise iron and steel bars by passing currents in various ways through them, all of which failed; but Œrsted's grand discovery gave the clue as to the proper way to do it. In the same year that his discovery became known, both Davy and Arago solved the problem of how to magnetise an iron or steel bar by means of a current. Instead of passing the current through the bar they wound a wire in the form of a spiral round it, and sent a current through this wire. The bar forthwith became a powerful magnet, and in the case of iron, when the current ceased, the bar immediately lost its magnetic properties. The magnets, which can be thus made, are far more powerful than any which can be made by any other known means, and what is of far more importance, they are perfectly under control, losing their magnetism at the same instant that the current stops; and when the material is soft wrought iron, there is scarcely any trace of residual magnetism left in them. A magnet of this form is called an *electro-magnet*, and much credit is due to Sturgeon for the various improvements which he made in it. The value of these improvements will be better appreciated when we consider that there is scarcely a piece of electrical machinery at present in use which does not contain as one of its vital parts the electro-magnet in some form or other. Dynamo-machines, arc-lamps, motors, electric-bells, telephone transmitters and receivers, fire-alarms, and telegraphic receivers, all contain in a more or less disguised form the electro-magnet. It is an instrument so absolutely under control, and, when well designed, so capable of exerting great force, that we may look upon the time of its introduction as the date which marks the origin of electrical engineering proper. An electro-magnet is usually made by taking a coil or bobbin of wire through which a current is flowing, and introducing a piece of iron into it so as to form a core. The whole arrangement then acts in every respect like an ordinary magnet, but its strength depends upon the strength of the current and the quality of the iron. The direction of the current in the coil determines which end of the iron is to be the north and which the south pole. If the direction of the current is reversed, the polarity of the iron is reversed at the same moment. It is found that either two north or two south poles will repel one another, while a north and a south always attract one another. Dealing with an electro-magnet, it can thus be made either to attract or repel the pole of an ordinary magnet placed near it, by making the current circulate in the proper direction through the coil. Can anything, then, be simpler than to construct a machine in which the pole of an ordinary magnet is placed near that of an electro-magnet, and is attracted and repelled alternately as the current is reversed in the coil? A reciprocating motion of the magnet is thus procured, which is precisely similar to that which takes place in the cylinder of the ordinary steam-engine; in a like manner, therefore, it can be made to do useful work by a suitable system of gearing. A machine of this kind is called a *motor*, and the principle just described applies to the construction of every type now in use; but it must be clearly borne in mind that an electro-magnet can in every case be substituted for an ordinary one, and usually with advantage. In modern machinery of this kind, the ordinary or permanent magnet has become nearly obsolete; the electro-magnet possesses such enormous advantages over it that it has almost entirely taken its place.

Jacobi, of St. Petersburg, constructed an engine of this kind in 1834, and five years later he propelled a boat by its means. Henry, in 1831, and Ritchie, in 1833, also constructed engines on the same principle, and though the attempt was made by many to construct one which would be a commercial success, still they all met with the same fate—complete failure. There were many highly-ingenious pieces of apparatus constructed, but they never got beyond the stage of being interesting working models. As a matter of fact, it would have been impossible for their efforts to have ended in anything but absolute failure. The reason is not far to seek. In order to construct a powerful electro-magnet, which is absolutely essential for a powerful machine, a strong current is necessary. This current was supplied by the consumption of zinc in the Voltaic cell; in other words, zinc was the fuel which was consumed or burnt up in the cell in order to supply the current to the motor. Let us compare it with the fuel which is consumed in order to supply steam to the steam-engine. A pound of coal is capable of giving out about four times as much work, when burnt, as a pound of zinc, and zinc is about fifty times as dear as coal; therefore, for the same amount of money, we can get about two hundred times as much work from coal as from zinc. This is on the supposition that both methods of working are equally efficient; but it is found in practice that the electrical method of consuming the fuel has an advantage of about four to one, which leaves a final advantage of about fifty to one in favour of coal in the steam-engine against zinc in the cell. It was clearly impossible that the electric motor, under the then existing circumstances, could ever compete commercially with the steam-engine. This was the all-important point which the experimenters at that time did not realise. The one thing that was wanted in order to render the solution of the problem possible was a cheaper method for generating a current. This the progress of the science has now supplied by the evolution of the dynamo-machine; and the successful application of the motor in the industries has now become an accomplished fact. It is true that the power which can be obtained from the motor comes originally from the energy stored up in the coal. There is necessarily a certain loss in each of the changes which the energy has to undergo, but, complicated as the process may seem, it will compare most favourably with that which is adopted in order to drive the motor by a current generated by the consumption of zinc in the Voltaic cell.

AGRICULTURAL CHEMISTRY.—II.

BY SIR CHARLES A. CAMERON, M.A., PH.D.

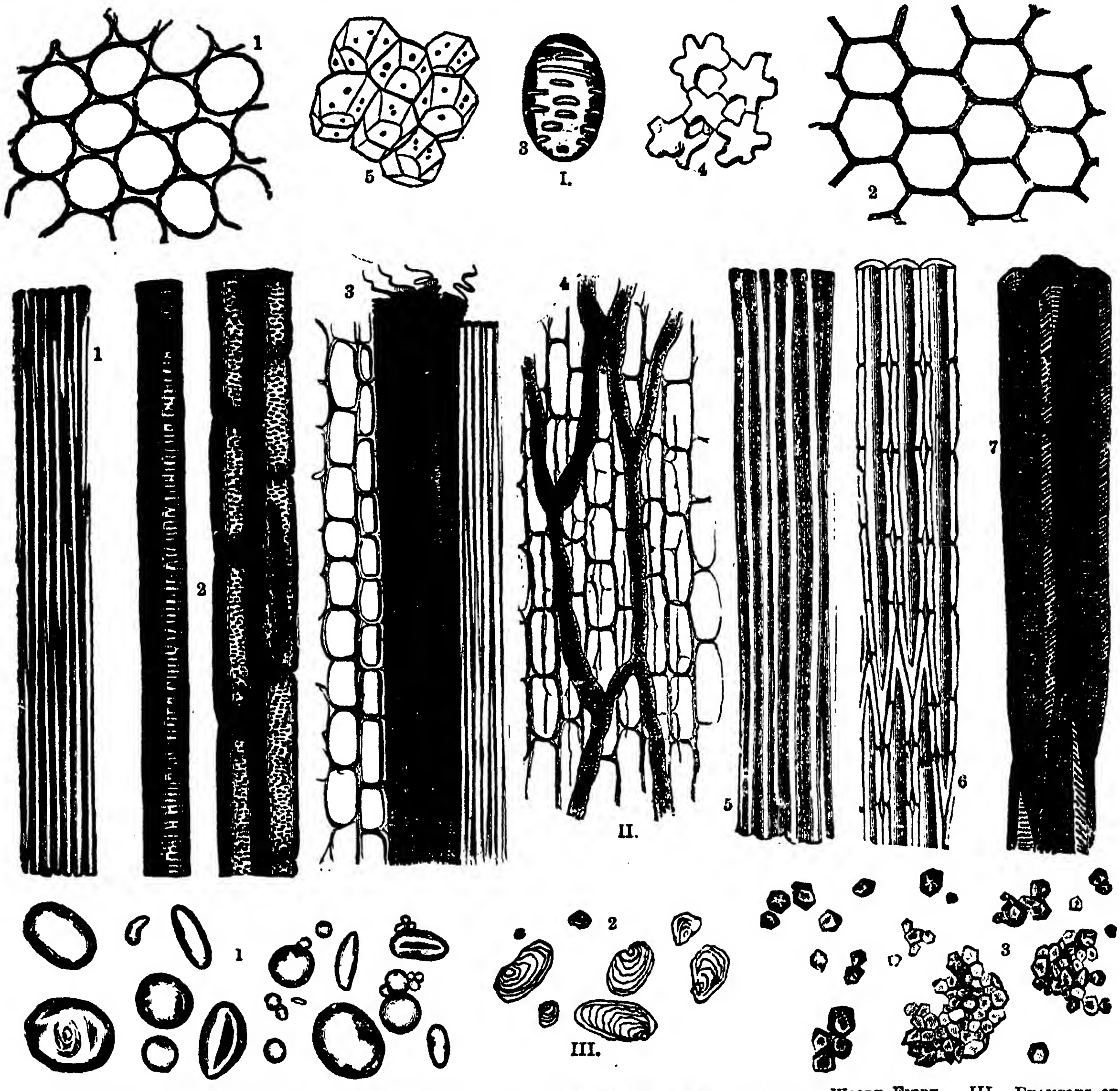
CHAPTER II.—THE ELEMENTARY PARTS OF PLANTS.

The almost infinite variety of form, colour, weight, and every other attribute of the multitudinous objects in the vast storehouse of Nature, naturally suggests to most minds the idea that the number of raw materials from which they have been elaborated must necessarily be very great. We have, however, shown in a previous chapter that such is not the case, and that the number of first principles is very small. A mass of any one of these first principles or elements is, there is good reason to suppose, an aggregation of minute particles, which, from a belief in their indivisibility by chemical or physical means, are termed *atoms*.* In a strictly mathematical sense we cannot consider atoms to be indivisible, because matter, however minute in quantity, possesses weight, length, breadth, thickness, and extension. An atom, however, may be regarded as an aggregation of innumerable smaller particles, which cannot be separated from each other, at least by any power at man's disposal. The Greek philosopher, Democritus, by an ingenious illustration exhibited intelligibly the impossibility of dividing an atom. He likened the matter of which our earth is composed to the starry firmament, each member of which being so small compared with its distance from the others and the immensity of the universe, may really be termed an atom; for although it is composed of a number of particles of matter, yet all these particles are bound together by a force which no external influence can affect. Neither can its form or its distance from the other heavenly bodies be altered. From this point of view the universe may be regarded as a vast aggregation of indivisible and unchangeable atoms.

As in the inanimate the apparently insignificant atom is believed to play the most important part, so in the animate creations we find the essential functions of life discharged in those parts of animals and plants which are apparently so low in the scale of organisation as to be all but unworthy of our attention. Animate as well as inanimate matter is composed of small and, in a physiological sense, indivisible atoms. As an amorphous (uncrystalline) mass of mineral matter possesses

* From the Greek words, *a*, a privative particle, and *temno*, I cut.

only the properties which distinguish a single atom of it, so also are there immense masses of living matter (simple cellular plants) composed of *organic atoms*, each of which possesses all the properties which we recognise in their aggregated unity. And again, as the grouping of atoms of a particular kind of substance—say carbon—into crystalline masses causes them are numerous points of resemblance between the two classes of atoms, there is believed to be this important difference—the inorganic atom is conceived homogeneous, whereas the atoms of organised structures are, so to speak, heterogeneous. But certain botanical microscopists affirm that the cell takes its origin from an exceedingly minute and homogeneous particle of



I. EXAMPLES OF FORMS ASSUMED BY VEGETABLE CELLS. II. EXAMPLES OF FORMS ASSUMED BY WOODY FIBRE. III. EXAMPLES OF FORMS ASSUMED BY STARCH GRANULES.

Ref. to Nos. in Figs.—I. 1, circular vegetable cells; 2, polyhedral form induced by compression; 3, ovoid or spheroid cell; 4, stelliform cells; 5, angular cells. II. 1, woody fibre magnified; 2, striated and punctated vessels of melon; 3, spiral fibres or tracheæ of plants; 4, lactiferous vessels of celandine; 5, librine fibres of hemp; 6, woody fibre of the fir; 7, scalariform vessels of the tree-fern. III. 1, arrowroot starch; 2, wheat starch; 3, rice starch.

to acquire in combination properties which individually they did not possess, so the various arrangements of atoms of organic matter give rise to structures which manifest properties unrecognised in the simple atom.

The organic atom is simply the *nucleated* cell of the vegetable physiologist. Its external configuration is probably similar to that of the mineral atom, and as the latter gains in weight at least in different inanimate substances, so does the former vary in size in different animate bodies. Although there spherical form, which they have termed the *cell germ*. It is, however, not probable that this germ is the ultimate atom of vegetable substances, inasmuch as it is easily visible through the microscope, whilst the same instrument reveals the existence of plants so minute that hundreds of millions occupy the limited space of one cubic inch without interfering with each other! As each of these minute organisms must be composed of numerous parts or atoms, excessive minuteness of the latter presents an impassable barrier to all save speculative inquiries

relative to their size and form. The cell may, therefore, for the purposes of research, be regarded as the elementary organ or atom of organised structures.

The cell consists of a little bladder formed by an elastic transparent and extremely thin membrane. The cavity contains semi-liquid and sometimes gaseous matters. The wall of the cell is apparently devoid of definite structure; it is composed chiefly of *cellulose*, a substance resembling starch in composition. On the inner side of the cell there is a thick, mucilage-like substance, termed *protoplasm* or *formative layer*. In the cell there is a small spherical, termed the nucleus, which closely invests a smaller body—according to some, a cavity—called the *nucleolus*. The nucleus and the protoplasm are destined to form into new cells.

The shape of cells is influenced by the condition under which they are developed. When their growth is unopposed, or when they are exposed only to gentle and equable pressure, their form is most frequently that of a sphere or spheroid. Owing to unequal pressure, cells, however, are found to present a great variety of forms, many being tube-like. The engraving in the preceding page (Fig. I.) exhibits the varied forms assumed by cells.

Wood is in great part composed of tube-like cells. When the tubes are very long and narrow, they are termed *vessels*. Cells vary much in size; sometimes they are easily recognisable by the unassisted eye; but in general they are at least only the one-thousandth of an inch in diameter.

In the lowest forms of vegetable life the cells are all but unconnected, and all perform the same functions; but in the higher forms of plants they coalesce and form structures, each of which discharges a different function in the economy of the plant. The least organised plants are termed *cellulars*. In these lowly forms of vegetable life the cells touch, each at a limited number of points, forming intermediate spaces, termed *intercellular canals* or *passages*. *Compact tissue* is produced when the cells lie close together. In the higher plants there are both *loose* and *compact* tissue. The majority of physiologists believe that there are numerous minute pores in the cell-walls; a very probable hypothesis, for otherwise it would be difficult to account for the fact that gases and liquids pass through the cell-walls.

The important food substances, starch and albuminoid bodies, are found in cells. The former, according to Mulder, is composed of nuclei, in which matter destined for the nutrition of the offspring of the plant is stored up. The engraving (Fig. III.) represents the various appearance of some of the starch granules contained in cells. In the cells we also find the matter termed *chlorophyll*,* which confers upon plants their green colour. The circulation of the juices of the plant is carried on by means of the cellular tissue, and in thousands of species the circulation is solely carried on through this agency. Owing to the looseness of the cellular tissue, and to the tenacity of the individual cells, these structures render plants strong and elastic at the same time.

The substance of which cell tissue is formed is supposed to consist of extremely minute round bodies placed side by side, leaving very minute spaces between them. In young cells the tissue or membrane is extremely thin, and is translucent; but after a time it generally becomes thicker and more opaque. Chemically, the membrane is composed of carbon, hydrogen, and oxygen, and is almost identical in composition with starch. By chemical treatment it is readily converted into a species of sugar. In certain parts of numerous plants the cell-wall is lined with a very hard substance, termed *sclerogen*, which appears to be almost, if not quite, identical in composition with the cell-wall. The hardness of various kinds of nuts is due to the sclerogen in their cellular tissue. The hardness of wood is in great part due to the sclerogen or lignine contained in its cells. Cellulose occurs nearly pure in elder pith, cotton, and linen. It constituted the celebrated *papyrus* or paper so extensively employed by the ancient Egyptians and Greeks. Examples of varieties of plant-fibre are given in Fig. II. in the preceding page.

Elementary fibre is identical in composition with elementary membrane, on the side of which it is deposited from the protoplasm. It is solid, body generally rounded, and almost always translucent or transparent. Its function is to sustain the elementary membrane, and to prevent any of its folds from coming into actual contact with each other. In *fibro*-cellular tissue we find cells having one or several fibres wound in a spiral direction round its inner side. As the sides of cells containing fibres are kept well apart, they are generally found to contain air.

* From the Greek *chloros*, green, and *phyllon*, a leaf.

Woody fibre consists of long tubes (formed from cells) having tapering extremities; their ends overlap each other. They are more or less filled with sclerogen or lignine. This kind of tissue is particularly abundant in forest trees.

Vascular tissue is found only in the higher forms of vegetable life. It consists of long unbranched tubes or ducts, which, however, are only a series of cells opening into each other. These tubes are believed to be chiefly employed in conveying air throughout the vegetable mechanism, and they may be regarded as somewhat analogous to the lungs of animals. Woody tissue is a species of vascular tissue, and so also are the branched tubes termed lactiferous vessels, in which the milk-like liquid found in certain plants is contained.

MINERAL COMMERCIAL PRODUCTS.—III.

LEAD.

This metal, the heaviest of the baser metals (sp. gr. 11·45), is soft, easily fused, and very slightly sonorous. It is largely used in roofing, lining, plumbing, and bullet and shot making. It also enters into the composition of pewter, solder, and type-metal; and in its chemical combinations it forms litharge (the oxide), a yellow paint; red lead (red oxide), a cheap substitute for vermilion; white lead (carbonate), manufactured on an immense scale for the painter; and sugar of lead (the acetate), of great value to the chemist. These substances are highly poisonous.

The most abundant and important of the ores of lead is *galena*, a sulphide of the metal, yielding 86 per cent. of lead, and almost always containing silver, which is separated when the quantity is not less than four ounces to the ton. The other ores are: the *carbonate of lead*, the *vanadiate of lead*, the *cupreous sulphate of lead*, and the *arsenio-phosphate of lead*. Galena is found very abundantly in the limestones of the Carboniferous series, and to a less extent in older rocks. Its reduction is effected by pounding, washing, and smelting in a reverberatory furnace. Lead-mining is carried on in Britain (Northumberland, Cumberland, Durham, Derbyshire, Flintshire, Cornwall, Isle of Man, and Lead-hills), also in Spain and Portugal, France, Belgium, the Harz Mountains, Saxony, Rhine Provinces, Bohemia, Carinthia, Hungary, Norway, and Sweden; Altaï Mountains, China, and Indo-Chinese Peninsula, South Africa, Peru, California, United States, and Canada.

The annual supply of lead from the different countries of Europe is—

	Tons.		Tons.
Britain	51,000	Spain	313,000
Austria (with litharge)	6,800	Sweden	500
Zollverein	38,800	France (metriquintals)	20,000

ZINC.

This metal, of a bluish-white colour, and specific gravity about 7, has the remarkable peculiarity of being malleable and ductile only between the temperatures of about 250° and 300° Fahr., and of retaining its malleability when cooled. It forms a cheap substitute for many of the applications of lead, such as tanks, pipes, roofs, and for bronze in ornamental works. It enters into the composition of brass, and is now extensively employed in domestic manufactures, printing, engraving, sheathing of ships, coating of galvanised iron, electrical apparatus, and medicine. Its oxides form valuable white and grey paints.

The principal ores of zinc are, *calamine*, a carbonate (ZnO,CO_2); *blende* or *blackjack*, a sulphide; and a silicate, or *electric calamine*. They occur often in association with the ores of lead, and frequently with the ores of copper and tin, chiefly in limestones of the Carboniferous and Devonian systems. The pure metal is obtained by roasting and distillation, as it is very volatile at a red heat. The ores are largely worked in Belgium, Silesia, Rhine Provinces, and Hungary. Zinc is also produced

in Flintshire, Derbyshire, Cumberland, Cornwall, Devon, Ireland, Wales, Isle of Man, Sweden, Bohemia, Carinthia, Spain, the Harz, Canada, New Hampshire, and New Jersey, in which last place the metal occurs in the mineral red zinc ore, an oxide of zinc.

The average annual production of zinc from Europe and the United States is:

	Tons.		Tons.
Britain	24,460	Sweden (ore)	10,000
Silesia	36,000	Zollverein	76,000
Austria	1,500	Belgium	16,000
Spain	1,000	United States	5,000

ALUMINIUM.

This metal is white, resembling silver, and is of low specific gravity (2·6). It exists abundantly in Nature as the metallic base of argillaceous and felspathic rocks, which are silicates of alumina, and as sulphate of alumina, an important constituent of the alums. The pure metal has lately been obtained in quantities available for manufacturing purposes; and from its extreme lightness, its freedom from tarnishing, and its sonorousness, it promises to become a most useful product. The metal can be separated from the earth alumina, or from the chloride; but it is obtained economically only from *Cryolite*, a double fluoride of aluminium and sodium, found in Greenland.

ANTIMONY.

Antimony is white and brittle, with a specific gravity of 6·8. As a simple metal it is not used, but it forms valuable alloys. With lead and bismuth it is largely used in the preparation of type-metal, which consists of 6 parts of lead and 2 of antimony; with lead and tin for plates on which music is engraved, and with the same for stereotype metal. A small proportion of antimony combined with tin forms hard pewter; and with tin, bismuth, and copper, the white or Britannia metal. It is also very extensively employed in medicine. It occasionally occurs in a pure state, but usually combined with sulphur, or sulphur and lead; it is also found in combination with arsenic, and with nickel, silver, and copper.

Grey antimony, a tersulphide, affords nearly all the antimony of commerce. It is found in Hungary, Saxony, and the Harz, Belgium, France, Italy, Spain, Siberia, Mexico, Malacca, the Indian Archipelago, and was at one period produced in considerable quantities in Cornwall and Dumfriesshire; but now the principal part of our supply of antimony is from Borneo and the East Indies.

Central Italy furnishes 700 tons; Spain, 58 tons.

BISMUTH.

Bismuth is a brittle reddish-white metal (sp. gr. 9·9) which fuses at a very low temperature. It fuses still lower in combination with lead and tin, with which it is used as a solder, and with which it also forms the metal called "Newton's," fusible at the boiling-point of water. It enters, too, into the composition of Britannia metal, pewter, and type-metal, and is of some use in medicine. It is found, tolerably pure, usually associated with ores of tin, copper, and silver, in Cornwall, France, Bohemia, Saxony, and Sweden.

COBALT.

Cobalt is a white, brittle, and very tenacious metal. Its specific gravity is 8·5, and it is strongly magnetic. It is very useful in its chemical preparations as producing fine colouring substances, chiefly blue, such as smalts, cobalt-ultramarine, and zaffre or saflor (a corruption from sapphire). The principal ores are cobalt-glance, a combination with arsenic, the black oxide, and cobalt-bloom; they are found in Norway and Sweden, Saxony, Hungary, Rhenish Prussia, and the United States. The annual yield of zaffre or smalt amounts to, in Saxony, 8,000 cwt.; Bohemia, 4,000 cwt.; Prussia, 600 cwt.; Norway, 4,000 cwt.

NICKEL.

This metal is also found combined with arsenic. It is white, malleable, and but slightly affected by air and moisture. Its specific gravity is 8·5, and it is magnetic until subjected to great heat. With copper it forms German silver, and its alloys form excellent bases for electro-plating. A fine green colour is obtained from its preparations. Nickel has been used in the United States for coin. Its chief ore, "kupfer-nickel" or speiss, often associated with cobalt, is found in Westphalia, Saxony, Hesse, Hungary, and Sweden. Nickel occurs in meteoric iron.

ARSENIC.

Metallic arsenic is grey, highly lustrous, crystalline, and brittle (sp. gr. 5·7). The arsenic of medicine is the white oxide, or arsenious acid, a virulent poison; this is also largely employed in preparing some of the finer skins and furs of Russia. This metal enters into the composition of some valuable pigments, especially a brilliant green and an orange red. It is also combined with lead in the manufacture of shot. Arsenic is rather widely diffused; and although sometimes pure, it is usually found combined with other metals, with sulphur, and with oxygen. The chief amount is obtained from the arsenides of iron, nickel, and cobalt, and the supply is chiefly derived from Bohemia, Hungary, Saxony, Salzburg, Transylvania, Rhine Provinces, and France. *Realgar*, a red sulphide (AsS_2), is found in Bohemia and Saxony; and *orpiment*, another sulphide (AsS_3), a fine yellow, in China and South America.

Arsenic is also procured from the tin mines of Cornwall; the annual produce of the metal from this source being more than 1,000 tons.

MANGANESE.

Manganese oxidises at ordinary temperatures, and is never used in the arts in the pure state. It is of a reddish hue, brittle, so hard as to scratch glass, and has a specific gravity of 7·13. The binoxide (MnO_2) is an important article of commerce, largely employed in glass manufacture and for colouring pottery, and by the chemist in the preparation of oxygen. Sulphate and chloride of manganese are used in calico printing: the former gives a valuable brown dye. It is found that a slight addition of this metal much improves the cast steel made from British iron. The principal ores of manganese are *Pyrolusite* and *Psilomelane*, both binoxides, the former anhydrous, the latter containing 1 per cent. of water. *Wad*, an impure manganese ore, may be employed, like the preceding, in bleaching, and also for umber paint. Manganese ores are procured from the Harz Mountains, Piedmont, France, Spain, Nova Scotia, Somerset, Devon, Isle of Man, and were formerly obtained from Cornwall, Italy, etc. Britain produces 5,000 tons.

CHROMIUM.

This metal, in its pure state brittle, difficult of fusion, and like iron in colour, is important in the arts for the beautiful colours produced by its combinations. The most important of these are the sesquioxide of chromium, a fine green, bichromate of potash, and bichromate of lead, yellow and orange. The principal ores are chromic iron (chromate of iron) and chromate of lead, the former occurring usually in serpentine rocks in the Shetland Isles, France, Norway, and the United States, and the latter in Siberia, the Urals, and Brazil.

TECHNICAL DRAWING.—IV.

LINEAR DRAWING BY MEANS OF INSTRUMENTS (*continued*).

Returning now to the practice of drawing by means of instruments, a useful series of examples is here given for the student's use.

The subject of which Fig. 12 is the plan and Fig. 13 the section, is a network platform for a foundation where the soil is of a soft character, and liable to be pressed outward by the weight resting upon it, but still not sufficiently so to render absolute sheet-piling necessary. Strong piles (*c c c c*) are driven down to the firm soil, and these are connected by horizontal planks (*e e*), placed on each side and bolted through the piles.

Now in the space left between these planks a wall is formed of timbers, *d d d d*, which are driven down by hand-ramming, not extending downward further than the circumstances may render necessary.

These planks are jointed in various ways, with some of which you will become acquainted in the study of "Building Construction;" Fig. 14, rebated; Fig. 15, splayed at one edge and recessed at the other; Fig. 16, ploughed and tongued. In the example, the tongue is shown square and tapered, and in Fig. 17 it is worked in the dovetail form, whilst Fig. 18 shows the planks joined by an inserted tongue.

Now, to draw this series of examples—

First draw the piles, *c c c c* (Fig. 12), and continue the lines forming the edges of them, so that these may give you the sides of the piles shown in the section (Fig. 13).

Next draw the top of the wall of planks between the piles, and in the example it will be seen these are one-third the thickness of the piles; therefore, divide the edge of one of the piles on each side into three equal parts, and use the middle division for the thickness of the wall. This thickness, again, projected upwards, will give the elevation of the edge of the planks (*d d*). Now outside and inside of the piles draw the tying-planks, *e e e e*, and project them on to Fig. 13, *e e e e*, where it will be evident they will appear as sections.

Next draw the lower course of sleepers, *a a a a a*, and the elevation of them shown at *a*, in Fig. 13; then follow in their order the upper course of sleepers (*b b b b*), their projection in section (*b b b b*), and in these last the flooring of the platform which has not been shown in the plan.

The difference in the form of the piles when used separately, or at angles of foundations, and those called sheet-piles, will be fully described when treating of the principles of foundation in "Building Construction." The cuts (Figs. 19, 20, 21, and 22) are here introduced in order that they may be used as studies for drawing and shading. It may, however, be well to inform you that the points of the single or corner piles (Fig. 19) are four-square, whilst those of sheet-piles are only bevelled from *two* sides, and the edge is cut so as to slant downwards (Fig. 20).

Piles are generally worked of square timber, and if the trees admit of it, those which are to be rammed entirely into the ground are mostly slightly tapered downwards throughout their whole length, and are shod with iron at their points (unless the piles be small and the ground not very hard); and an iron ring is placed around the upper end, to prevent the piles from splitting by the violence of the blows necessary to force them down.

Sometimes, however, the piles which are to be driven quite below ground may be used without squaring; two illustrations of such (Figs. 21 and 22) are here given, to afford practice in shading cylindrical bodies.

Having pencilled and inked the outlines of the four piles shown in the example, wash over the part representing wood

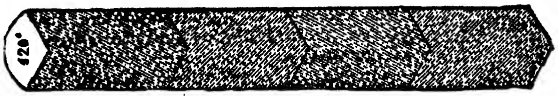


Fig. 15.

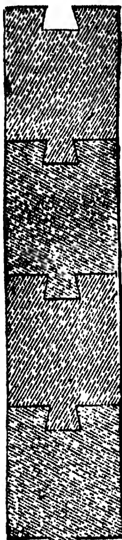


Fig. 17.

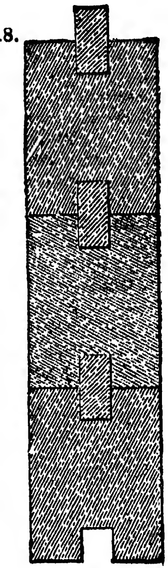


Fig. 18.

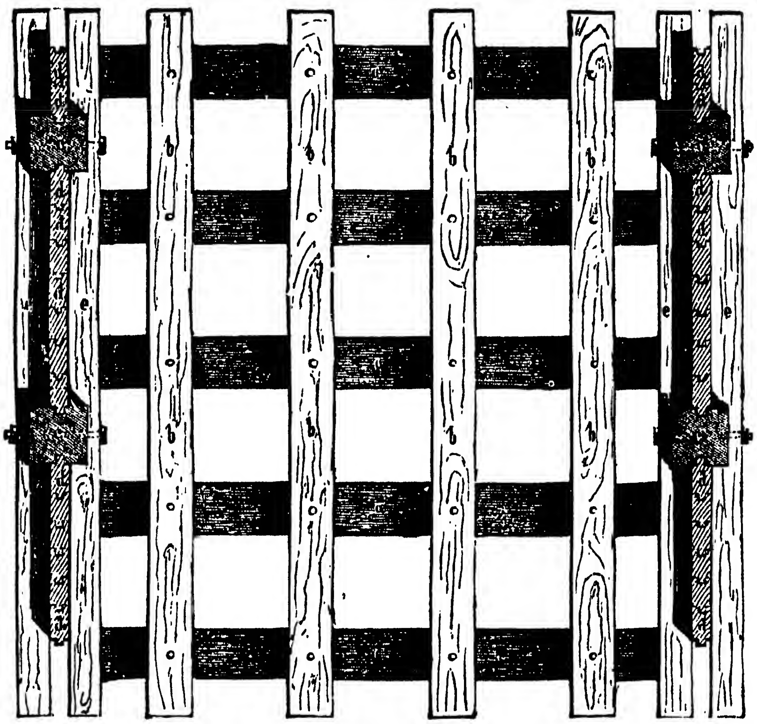


Fig. 12.

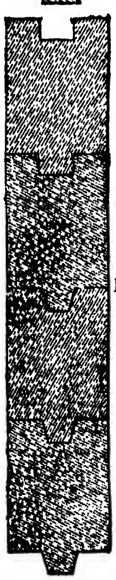


Fig. 16.


Fig. 14.

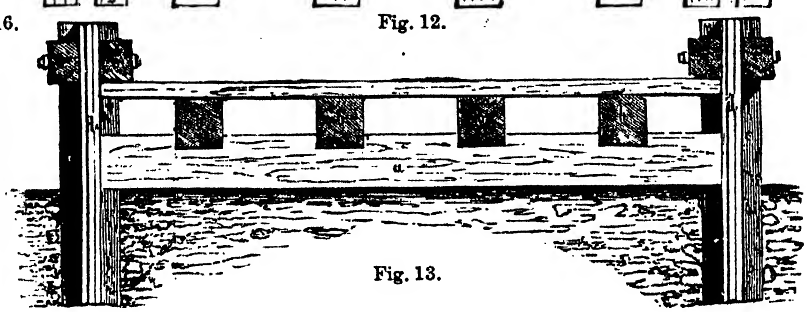


Fig. 13.

with a pale tint of raw sienna. In the two square piles this wash may be perfectly flat, but in the round piles the tinting must be in accordance with the form.

It will be evident that when a cylindrical body is placed upright, the light will fall in a stream straight down the part which projects the most, and this part must, therefore, be preserved as bright as possible; in fact, there must be a perfectly white streak extending all the way down.

To effect this, you must use two brushes, the one rather larger than the other. Take some colour in the smaller one, and dip the other in water; touch the points of both on another piece of paper, so that they may not be overcharged, and by gently turning each round as you draw it along the waste paper you will bring the hairs to a point.

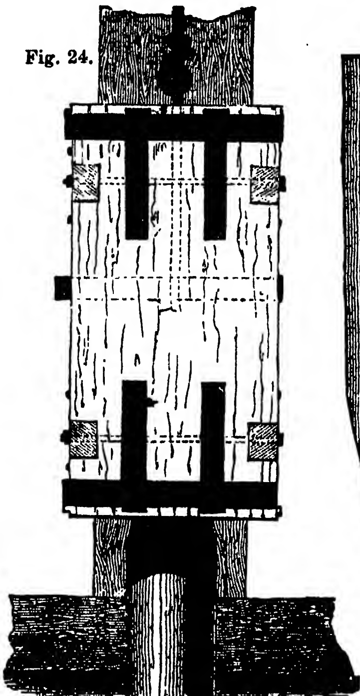
Now commence by drawing the brush containing the colour down the left side of the round pile, carefully avoiding passing over the line by which it is bounded. In this way colour a strip about one-eighth of an inch wide; do not leave a *pool* of colour, but merely tint the paper. Before this has time to

The rammer, which is made of beech or other hard wood, should be tinted of a lighter colour than that given to the guide-posts.

The pile is to be coloured and shaded as in the previous examples, but you will observe that there is on it the shadow cast by the rammer above; this is called the "cast-shadow," and must not have its lower edge smoothened off, as the sharp edge of the bottom of the rammer will cause the shadow cast on the cylindrical pile to be very well defined.

Fig. 24 is the front elevation of the same object, and will give further practice. The student is urged to observe the forms and tones of shadows cast by different objects; this he can easily manage—a cubical piece of wood or two, and a cylindrical piece, may be disposed in hundreds of ways, each affording a new study. This is the only way to gain real practice; for so long as the pupil only copies, he is merely repeating other men's works, and will only gain manual practice; *whilst by studying and making his own observations he will be laying up a store of information of which he will hourly find the value.*

Fig. 24.



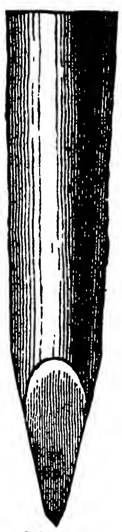


Fig. 21.

Fig. 19.

Fig. 20.

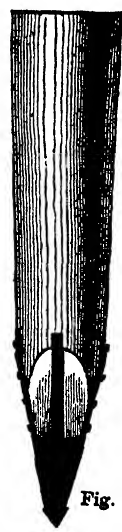
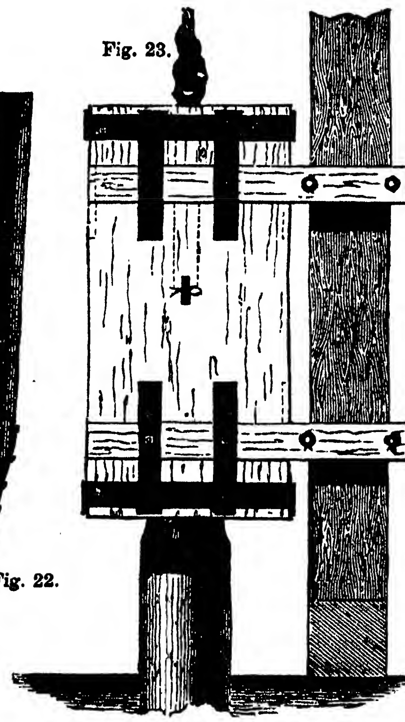


Fig. 22.

Fig. 23.



become dry, take your water-brush, and passing the point down the *inner* side of the part you have coloured, soften the edge away so that the colour may merge gradually into the bright white. Leave about the eighth of an inch quite dry, then pass your water-brush down, and next to this the colour, so as to produce the effect as on the other side; the colour becoming gradually fuller as it becomes further removed from the light.

Whilst the dark strip is still moist, wash off its edges, and merge it off into the local colour of the pile, and this should be done so gradually that as you ought not to be able to discover where the white light merges into the raw sienna, so you should not be able to discern the meeting of that colour with the sepia; but do not work your brushes up and down so as to produce a sleek or woolly effect. The shading and tinting should be bold and clear: a little practice will enable you to accomplish this. You are therefore advised to repeat such studies until you succeed. The iron shoe of the pile will, of course, be coloured with pale indigo.

Fig. 23 will afford another example for colouring and shading. The drawing represents the side elevation of the monkey (or rammer) and guide-posts of a simple pile-driving machine, with head of a round pile.

The shading is to be done in sepia; in the square piles this will simply consist in tinting the shaded sides with a flat tint. In the round piles, however, the shading must be managed in a similar manner to the colouring; dipping your middle-sized brush into the sepia, colour a strip the whole length of the pile. This darkest part, however, you will observe, is near, but *not* really on the outer edge of the cylindrical body. Further to the right side, you will notice the shade becomes lighter, and this is called the *reflected light.*

It may happen with beginners that the tints may not dry quite as smooth or as flat as they expected—irregularities, dark patches, or light spots, may appear. In the one case, a brush just moist should be worked over the dark part, by which means some of the superfluous colour may be removed. In some cases it may be necessary to rub the spot with a soft piece of india-rubber or bread. If neither of these processes is successful, a sponge should be drawn over the whole, and the work repeated when dry. In case of light spots appearing, they should be touched with the *point* of a brush containing colour; but care must be taken that *only* the light spot is touched. This is called *stippling,* and should only be used as a remedy. Tinting and shading should always be done in as free and bold a manner as possible.

VEGETABLE COMMERCIAL PRODUCTS.—II.

FARINACEOUS PLANTS (*continued*).

(*c.*) *The Leguminosæ* (*Pulse Family*).

This great natural family of plants contains numerous species with wholesome nutritious seeds, which, under the general term *pulse*, form important articles of commerce. These legumes comprise, in temperate climates, the Common Pea (*Pisum sativum*, L.), the Horse Bean (*Faba vulgaris*, Moench), the Haricot or French Bean (*Phaseolus vulgaris*, Sari), the Lentil (*Ervum lens*, L.); and, in the tropics, the Ground Nut (*Arachis hypogæa*, L.), the Chick Pea (*Cicer arietinum*, L.), and the Carob Bean, or St. John's Bread (*Ceratonia siliqua*, L.).

The legumes of temperate climates are familiar plants, and their mode of culture well known. Peas, beans, and lentils are grown in great quantities in Poland, Prussia, Pomerania, Denmark, East Friesland, and other countries. They create considerable business in the large sea-port towns on the Baltic and German seas, whole cargoes being brought to those places as provisions for ships. In 1882, 2,114,950 cwt. of peas were imported to this country, chiefly from Prussia and British North America; and the same year, 2,090,782 cwt. of beans were received, of which 1,243,016 cwt. were from Egypt, and the remainder from other countries. The tropical species of pulse are not so well known, and require description.

Ground Nut (*Arachis hypogæa*, L.).—This plant is cultivated in America, in the Southern States, and forms an important article of food in many parts of Africa. It is a low, creeping plant, indigenous to the western coast of Africa, with yellow flowers, having the general appearance of a dwarf garden pea, although more bushy. After the flowers drop off, and the pods begin to form, the stalk or support of the pod elongates, *thrusting the pod under ground*, where it comes to maturity. The seeds contain a considerable quantity of oil. They are roasted in the pods, and are sold in the United States in large quantities, being a favourite dainty with children. This plant is very prolific, and in warm climates requires but little care and attention in its culture. In the green state it is greedily devoured by cattle.

Carob Bean, or St. John's Bread (*Ceratonia siliqua*, L.).—The carob tree is peculiarly Oriental, and abundant in Palestine. It has large pods, the seeds of which are enveloped in a sweet, nutritious pulp. It is supposed to be the locust bean on which St. John the Baptist fed when in the wilderness. This tree is common in the Levant and the south of Europe, where its beans are used as food. Most of the carob beans imported into this country come from Sicily and Naples. During the Peninsular war the horses of the British cavalry were frequently fed on these beans.

Chick Pea (*Cicer arietinum*, L.).—This plant is a native of Southern Europe and the East. Its seeds are parched, and in Spain are sold in the shops for food. They are also abundant in the bazaars at Calcutta, and, under the name of *gram*, are sold as food for horses. Every part of this plant exudes oxalic acid, and it is used by the ryots of India in their curries instead of vinegar. When roasted, it is said to sustain life longer than other food in similarly small quantities; hence it is much used by travellers through the deserts, where the carriage of bulky food is inconvenient.

II. THE STARCHES OF COMMERCE, AND THE PLANTS WHICH PRODUCE THEM.

Starch is an abundant product of the vegetable kingdom, and is in large demand for domestic and manufacturing purposes. It exists in all mealy farinaceous seeds, fruits, and roots, differing in its appearance according to the plants from which it is obtained. Starch is the nutritive matter of plants, and is changed by light to *chlorophyll*, and by oxygen to a sugary gum called *diastase*, which is carried into the circulation for the support of the new growths of plants. Starch is turned blue by iodine, an excellent test for detecting its presence in plants.

The Arrowroot Plant (*Maranta arundinacea*, L.; natural order, *Marantaceæ*) is a native of tropical America and the West Indies. In arrowroot, tapioca, and sago, starch exists in a state of almost absolute purity. The arrowroot plant has large, herbaceous, very handsomely-striped leaves, and tuberous roots, which abound in fecula or starch. These roots are bruised, thrown into a vessel of water, and well stirred, when the fibrous portion comes to the surface, and is rejected, the starch settling at the bottom of the vessel as soon as the fluid is permitted to rest. This, after repeated washings, is dried in the sun, and constitutes the arrowroot of commerce, so much employed as a nutritive diet for invalids and young children.

Zamia integrifolia, Wild. (*Coontie*); natural order, *Cycadeæ*.—An arrowroot is now manufactured at Key West, in South Florida, from the stem of this plant, which is short and globular, and abounds in starch. This cycad, which was called by the Indians *coontie*, grows abundantly over an immense area of otherwise barren land. These manufactures bid fair to become as extensive and profitable as those of Bermuda, from whence at present our chief supplies of arrowroot are received.

Tous-le-mois, the starch of the rhizome of a species of canna (*C. coccinea ?*); natural order, *Marantaceæ*.—This starch resembles a fine quality of arrowroot; but the granules are much larger than those of any known starch. Tous-les-mois comes from the island of St. Kitts, and is only used as food.

Tapioca Plant (*Manihot utilissima*, Plum.; natural order, *Euphorbiaceæ*).—Tapioca is another form of starch, obtained by grating and washing the roots of this plant, which, under the name of manioc or cassava, forms a most important article of food in South America. This washing removes a narcotic poisonous principle which exists in the sap. The Indians dissipate it by heat, simply roasting the root. The starch thus washed, softened by heat, and afterwards granulated, constitutes tapioca. The ungranulated starch is the Brazilian arrowroot of commerce. The tapioca plant, in its native clime, is a shrub about five feet high, with roots which, when ripe, are about as large as a Swedish turnip, containing large quantities of this nutritive starch, and weighing sometimes thirty pounds.

The common starch of the shops, used in domestic economy, is obtained from wheat, rice, and potatoes, and is almost, if not entirely, home-manufactured.

Sago Palms (*Saguerus rumphii*, Wild.; and *Sagus lævis*, Goertn.).—Sago is obtained from several species of palm. The sago of commerce is, however, chiefly produced by these two plants. It is obtained from the cellular tissue, or pith, in the interior of the trunk.

The sago palm produces, like rice, a chief means of nourishment for millions in warm climates, since sago powder is generally used for making bread. It grows in the south of China, Japan, and all over the East Indies, but principally in the islands of the Indian Archipelago. This palm generally grows in swampy ground, where it flourishes best, a good plantation, being often in a marsh, selected for that purpose. Its trunk is from five to six feet in circumference, rising to a height of about twenty feet. The pith, from which the sago is obtained, is of no use until the tree is fourteen or fifteen years old. A single tree is said to yield from five to six hundred pounds of sago.

Most of the sago imported into the United Kingdom comes to us in its granulated form from the island of Singapore, where it is manufactured as follows:—The pith, which is soft, white, spongy, and mealy, is first removed from the interior of the stem, then bruised, and put into large tubs of cold water; the woody particles of course float, and are easily removed, and the weightier starch or sago powder settles at the bottom of the vessel. The water is then poured off, and the dried sago powder passed through small sieves made of the fibres of the palm leaves. In passing through these sieves, the sago powder acquires its granulated character. The preparation is then finished, and the sago is ready to be put into boxes, or placed in bags, for shipment.

The exports from Singapore in the year 1847 exceeded 6,500,000 lb., but are now much larger.

Sago is insoluble in cold water, but by boiling becomes soft, and at last forms a gelatinous solution. In England it is much used for puddings; and as it is both nutritive and easy of digestion, it constitutes an excellent article of diet for the invalid and the convalescent.

A great deal of German or potato sago, from the manufactories of Vienna, Nuremberg, Schweinfurt, Erfurt, Halle, etc., comes into the European market, and it is with difficulty distinguishable from the real East Indian sago.

III. PLANTS YIELDING SPICES AND CONDIMENTS.

Cinnamon (*Cinnamomum zeylanicum*, Nees.; natural order, *Lauraceæ*).—This plant is an evergreen aromatic tree, about

thirty feet in height, and indigenous to the island of Ceylon. Its leaves are oval, smooth, entire, with three prominent curvilinear ribs on the under surface. The young leaves are at first red, but change gradually to a yellowish-green, possessing the same flavour as the bark, but in a less degree; flowers panicled, white, with a brownish centre, devoid of fragrance, and about the same size as those of the lilac.

The inner bark of this tree constitutes the cinnamon of commerce, and the young twigs furnish the best. After the trees are nine years of age, the twigs are cut annually in the month of May, by the cinnamon peelers, or Choliahs, as they are called in Ceylon. This is done with a sharp iron instrument. The bark is removed by making a longitudinal and then a transverse incision into the shoot, inserting under the bark the point of the peeling-knife, and raising the handle of the knife as a lever. The next day the inner fibrous bark, in which resides the delightful flavour of cinnamon, is easily removed from the outer bark, and this, as it dries, curls up and forms quills. Before these quills become quite dry, hard, and brittle, the smaller are inserted into the larger; space in packing is thus saved, and compact sticks are formed, which are not so liable to breakage as the single quills. The wood from which the bark has been removed is sold for fuel.

"After hearing so much about the spicy gales from Ceylon," says Bishop Heber, "I was much disappointed at not being able to discover any scent, at least from the plants, in passing through the cinnamon gardens. There is a very fragrant-smelling flower growing under them, which at first led us into a belief that we smelt the cinnamon, but we were soon undeceived. On pulling off a leaf or a twig, one perceives the spicy odour very strongly; but I was surprised to hear that the flower has little or none."

Since neither the leaves nor the flower of the cinnamon-tree give forth any smell, it is only when the season arrives for gathering bark that the visitor to the gardens will enjoy the perfume of this plant. A walk through the cinnamon gardens during the busy season is truly charming. The grove is then full of fragrance, and a scene of cheerful industry. Everywhere are to be seen groups of Cingalese peeling the twigs, which they do with astonishing quickness, making a great deal of money whilst the season lasts. The Choliahs form a distinct caste, and are considered very low, socially, so that, according to Cingalese notions, it is personally degrading for any one else to follow the business. The largest of the cinnamon gardens in Ceylon is that near Colombo, which covers upwards of 17,000 acres of land.

Cinnamon-trees are preserved with the greatest care by their proprietors. By the old Dutch law the penalty for cutting or injuring them was amputation of the hand; at present a fine is imposed upon the delinquent.

In 1886 1,752,283 lbs. of cinnamon, valued at £58,909, were imported into England, a great part of which we re-exported to our colonies. Considering the extreme lightness of cinnamon bark, this is a large quantity. Cinnamon is usually brought home in bags or bales of from eighty to ninety pounds' weight. The best comes from Ceylon, but the cinnamon-tree grows plentifully in Java, Sumatra, Malabar, and Cochin-China, and it has been recently transplanted to the Mauritius, the Brazils, and Guiana, and to the West India islands of Tobago, Guadaloupe, Martinique, and Jamaica. The cinnamon produced in the West is, however, not so good as the Oriental.

Cinnamon is an aromatic tonic of an agreeable odour and taste, which acts as a grateful stimulant or carminative, creating warmth of stomach, removing nausea, expelling flatulency, and relieving colic or intestinal pain. It owes these properties to the volatile oil which it contains. Cinnamon is much employed as a condiment in culinary preparations, and is also frequently used for flavouring and disguising unpleasant medicines, or as an adjuvant—that is to say, an assistant.

Cinnamomum cassia seems to be the chief source of the *Cassia lignea*, or bastard cinnamon of commerce. This plant differs from the true cinnamon-tree in many particulars. Its leaves are oblong-lanceolate, and have the taste of cinnamon, to which also its bark bears a great resemblance, but is thicker, rougher, denser, and not so agreeable in flavour. It is cultivated in China, and is imported from Canton, *viâ* Singapore, in chests similar to those in which the tea is packed, with the appearance of which every one is familiar.

NUTMEG-TREE (*Myristica moschata*, Thunberg).—This tree, from twenty to twenty-five feet in height, strongly resembles our pear-tree in its general appearance, and also in its fruit, which is not unlike the round Burgundy pear. The leaves are alternate, smooth, entire, oblong-pointed, short-petioled, and aromatic when bruised; the flowers axillary, racemose, pale, bell-shaped, without a calyx. The fruit is a fleshy pericarp, opening by two valves when ripe, and displaying the beautiful scarlet reticulated arillus, or mace, enveloping the thin, dark-brown, glossy, oval shell, which covers the kernel, the nutmeg of the shops. Each fruit contains a single seed, or nutmeg. The mace and the nutmeg are both valuable spices. The former, although a brilliant scarlet colour when fresh, becomes yellow, brown, and brittle when dry.

Whilst the clove has spread over Asia, Africa, and the West Indies, the nutmeg-tree refuses to flourish, except in the islands of the Malayan Archipelago, where it appears to be indigenous. In 1819, 100,000 of these trees were transplanted by the British Government to Ceylon and Bengal, but the plantations were not successful. All attempts to introduce the nutmeg-tree into other tropical countries have failed.

The Dutch endeavoured to extirpate the nutmeg from all the islands of the Moluccas except Banda, and they had all the trees removed thither for better inspection; but this attempted monopoly was completely frustrated by the mace-feeding wood-pigeons. These birds conveyed and dropped the fruit beyond the assigned limits, spreading it over the whole of the islands of the Malayan Archipelago, from the Moluccas and New Guinea. It is singular that the Dutch should have failed to observe the habits of these birds: that they had not noted them appears to be proved by the very fact of their effort to establish a rigid monopoly.

The nutmeg and clove trees were first introduced into England by Sir Joseph Banks, as ornamental hot-house plants, about 1797.

Nutmegs and mace are employed chiefly as condiments for culinary purposes, for which they are admirably suited by their agreeable taste and stimulating properties. As remedial agents they owe their activity to the volatile oil which they contain, and when administered in moderate quantities, produce the usual effect of the other spices.

THE CLOVE-TREE (*Caryophyllus aromaticus*, Linn.; natural order, *Myrtaceæ*, the Myrtle family).—Cloves are the unexpanded flower-buds of this tree, which is an evergreen, the trunk rising from fifteen to twenty feet above the ground. The leaves are opposite, rigid, ovate-lanceolate, smooth, entire, petioled. The flowers are produced in great profusion, in short terminal panicles of from nine to eighteen in each bunch. The four leaves or sepals of the calyx are united; the base of the calyx is tapering and somewhat quadrangular. The corolla is red, and before expansion, forms a ball or sphere at the top of the calyx. The peduncles, or flower-stalks, are divided into threes, and articulated or jointed. This greatly facilitates the fall of the buds when the gatherers beat the trees with reeds or wands. They are also gathered by hand—a method adopted when the season has been unfavourable.

The clove-tree is a native of the Moluccas, where it was very abundant before the conquest of these islands by the Dutch. They extirpated it from all the Moluccas except Amboyna, and even there they allowed only a limited number of trees to be planted, lest the *price should fall too low!* This narrow policy stimulated other nations to try to get so valuable a spice. In 1770 the French obtained the plant, and introduced it into the Isle of Bourbon, and from thence to Cayenne and to their other possessions in America. But the best cloves still come from the Moluccas.

In addition to the supplies obtained from the East and West Indies, Great Britain also receives cloves from the Mauritius, and indirectly from Holland.

Dr. Ruschenberger, who visited Zanzibar, on the eastern coast of Africa, in 1835, thus speaks of the clove plantations there:—"As far as the eye could reach over a beautifully undulating land, nothing was to be seen but clove-trees of different ages, varying in height from five to twenty feet. The form of the tree is conical; the branches grow at nearly right angles with the trunk, and they begin to shoot a few inches from the ground. The plantation contains nearly 4,000 trees, and each tree yields, on an average, six pounds of cloves

annually. They are carefully picked by hand, and then dried in the shade. We saw numbers of slaves standing on ladders gathering the spice, while others were at work clearing the ground of dead leaves. The whole is in the finest order, presenting a picture of industry and of admirable neatness and beauty."

Cloves, when good, are dark, heavy, and strongly fragrant, the ball on the top being unbroken, and yielding oil when pressed with the nail. This oil is sometimes extracted, and the cloves so treated are mixed with the others. They are also sometimes adulterated with water, which they absorb readily, becoming plumper and heavier.

Cloves are much employed in cookery as a condiment, being the most stimulating of the spices. The oil of cloves is a popular remedy for the toothache, and the infusion a warm and grateful stomachic. Cloves are frequently employed by medical men to disguise the nauseous properties of their drugs, and thus render them more palatable to the patient.

THE ELECTRIC TELEGRAPH.—I.

By J. M. Wigner, B.A.

THE BATTERIES EMPLOYED—INSULATORS—LINE WIRES.

One of the features by which the present century has been rendered especially remarkable is the number and importance of its scientific inventions. Among these there is none more wonderful than the electric telegraph, and none which has more rapidly passed from being a mere scientific toy, valuable only for the elucidation of certain principles and facts, into becoming a great and important instrument in the conduct of our everyday business.

In 1819 Oersted made the discovery that a magnetised needle was deflected by the passage of an electric current along a wire placed near to it, and the mode of converting a bar of iron into a temporary magnet by means of the electric current was not discovered till several years subsequently, and already, at the present time, the messages weekly transmitted, in England alone, by instruments based on those principles are numbered by the hundred thousand; and there is scarcely any part of the globe that is not traversed by wires, along which our thoughts are constantly being flashed with a speed almost equal to their own.

In the articles on "Voltaic Electricity," which have already appeared in The Popular Educator, a general account has been given of the principle on which the various forms of telegraph instruments act. In the present series we propose to give a practical explanation of the construction of the different instruments and the manner of using them, so as to enable the intelligent amateur to construct such instruments for himself, and to help the telegraphist to understand the mechanism of the apparatus he is employing.

To transmit messages by electricity, it is, of course, necessary in the first place to have some means of generating an electric current of sufficient quantity and intensity We must further have some way of conveying this to the desired place, and also of causing it to produce at that place such effects as shall enable us to make our messages understood.

For generating an electric current, any one of the many forms of battery already described may be employed. The Cruickshank battery, consisting of alternate plates of copper and zinc excited by a solution of dilute sulphuric acid, was for a long time that generally adopted. Very frequently the cells were filled in with fine sand, over which the solution was poured. This form was commonly known as the Sand battery. Smee's and other forms have also occasionally been tried, but in almost all cases these batteries have now been superseded, and some modification of Daniell's sulphate of copper battery adopted. In the large cellars under the Central Telegraph Offices in Lothbury, there are thousands of cells of these batteries constantly at work. The standard form now adopted consists of a trough about two or two and a-half feet long. This is made of hard wood, and carefully coated inside with a resinous composition so as to prevent the acid from eating it away. Water-tight compartments are then fixed at about equal distances, so as to divide the trough into ten cells, and each of these is subdivided by a plate of porous or unglazed earthenware, represented in Fig. 1 by the thinner lines.

Plates of sheet copper are then cut about four or five inches square, and zinc is cast into thicker cakes of a similar size. A piece of copper and one of zinc are then connected together by a copper band riveted to each, as shown in Fig. 2. The band or strap is then bent in the middle, so that the copper plate may be in one cell and the zinc in the next. A lid is provided to each trough; this serves to exclude the dust, and at the same time, by checking evaporation, renders the action of the battery much more uniform.

The cells which contain the zincs are charged with dilute sulphuric acid, or with a solution of sulphate of zinc; those in

Fig. 1.

which the copper plates are placed contain a saturated solution of sulphate of copper (blue-stone), and, as the copper is precipitated on the plate by the action of the battery, the cells are usually filled up with crystals, so as to maintain the strength of the solution. If it gets exhausted, a portion of the zinc solution passes through the porous partition, and this metal is thrown down on the copper, rendering it almost black. For each equivalent (26 parts) of zinc dissolved in any cell, an equivalent (25½ parts) of copper is precipitated in the corresponding cell, and hence the copper plate increases in thickness while the zinc is eaten away.

When the acid becomes saturated with zinc the action of the battery is much diminished; a portion of the solution should therefore be removed, and the cell filled up with water.

Care must be taken not to let the zinc plate rest in contact with the diaphragm, as in that case metallic copper is deposited on it, and it is soon broken. After having been used the partition should also be kept moist, as, if allowed to dry, the sulphate of zinc effloresces round the edges and chips away small pieces.

The porous diaphragm does not entirely prevent the two solutions mixing, though it checks it very considerably. Some of the copper passes into the zinc cell, and, being there decomposed by the action of the zinc, falls to the bottom as a dark powder usually known as the "mud" of Daniell's battery. When an inner porous cell is used instead of a partition, it is usually greased all over, except on the portion opposite to the copper plate, so as to check as far as possible this mixture.

In some instances the porous diaphragm is entirely dispensed with, and the two solutions are kept separate by their respective weights alone. The copper solution, having the greater density, is first poured into the cell so as to half fill it; the acid is then carefully put in above it. In this form of battery the copper plate is placed at the lower part of the cell, and the zinc plate at the upper portion, so that the two do not overlap. The copper solution, however, in time mixes with the acid, and this battery is not very much employed.

Fig. 2.

In working batteries it is found that the same amount of zinc is consumed in each cell; it is advisable, therefore, only to employ plates of similar size in the same circuit. A single weak or defective cell will retard the passage of the entire current, and thus cause a very considerable waste of power.

It should be remembered that the *quantity* of electricity generated is not augmented by increasing the number of the cells; it is only the *intensity* that is thus affected. To increase the quantity we must increase the size of our cells, or, which practically amounts to the same thing, arrange two or three side by side, their zinc and copper plates being respectively connected. As a general rule, for distances of a few miles, a single trough containing ten or twelve cells is amply sufficient, provided it be working well. If it is losing its power, or the message has to be sent to a much greater distance, two or more of the troughs may be joined together.

Having now seen the manner in which the electric current is generated, we have next to ascertain the mode in which it can be conveyed to any required place. As we have already

learnt, the fluid very easily escapes, unless the conductor along which it is travelling is carefully insulated. When the wires are laid under the surface of the ground or at the bottom of the sea, this is accomplished by coating them with some insulating material in a way that will shortly be explained. In most cases, however, the lines are suspended in the air, which is, for all practical purposes, a non-conductor. All need for coating the wire is then at an end, and it is only necessary to make some arrangements which shall prevent the escape of the electricity at the points of support. This is accomplished by means of "insulators," a few of the forms of which were figured in the papers on "Voltaic Electricity."

In large towns the insulators are very frequently attached to the corners of lofty buildings, or to stacks of chimneys, and in this way much expense is avoided, and the wires are at the same time so much elevated that they do not interfere with the ordinary traffic of the streets. In the open country, however, they are supported on posts specially erected for the purpose, which under ordinary circumstances are placed at distances of about sixty yards apart, and the wires are about eighteen or twenty feet above the surface of the ground. Young fir or larch trees are usually chosen for the purpose, and roughly trimmed. Sometimes the wood is impregnated with a preservative compound to guard against decay. When this is not done, the pole is charred along the lower end for a length of several feet. The charred ends are sometimes allowed to stand in gas-tar for several hours as a further protection; but still, with every precaution, it is found that the post will decay at the ground-line, where it is exposed to the air as well as to the moisture of the earth.

In different parts of the Continent and in India, where wooden posts are far less durable, substitutes have been tried, and iron tubes and posts of different forms have been used to a considerable extent. The first cost of these is, of course, considerably greater, but in the long run a great saving is effected by their employment, and it seems probable that in England they may eventually become much more generally adopted. When the line is straight the strain is but small, but at an angle it is considerably increased, and struts or stays are usually employed to strengthen the posts.

In some places the plan has been tried of affixing the insulators to the stems of living trees, and this has been found to answer very well. The swaying of trees during storms is a slight objection, but a swinging insulator designed by a Prussian officer, Lieut.-Colonel Chauvin, meets this difficulty. The construction of this will easily be understood by reference to Fig. 3. The bent iron rod, A B, is cut at one end into a screw, and fixed firmly into the tree, while the other end is flattened out, and fastened by means of a screw. The insulator, C, is suspended from the ring D by the hook F, the end of which is turned back so as to prevent the wire jerking out when the tree is shaken. In the lower part of the insulator is fixed another hook through which the line wire passes. This is, of course, quite insulated from F, and is so bent that when the insulator swings to and fro with the wind, only the porcelain comes in contact with the tree or the support.

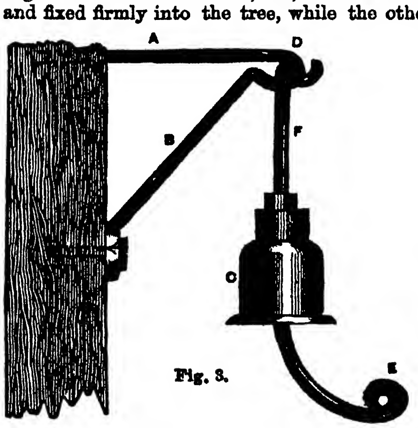


Fig. 3.

Almost every telegraph engineer has his preference for some special form of insulator, and hence there is a great variety. That most generally employed in this country is represented in Fig. 4. It consists of two inverted cups of brown earthenware, fitting inside one another. To the inner one is fixed the steel stalk by means of which the insulator is firmly bolted to the post, while round the outer is a groove to which the line wire is fastened. The two are fixed together by means of a non-conducting cement. On about one post in every ten a stretching-insulator is placed. The wire is found to give a little by the continued strain, and also to vary in tension with changes in the temperature. The result of this, if unchecked, would be to cause the wires to hang so loosely that when, as is generally the case, there were several on one post, they would strike against one another, and thus greatly interfere with the communication. These insulators are accordingly provided, and by means of them the wires are kept duly strained.

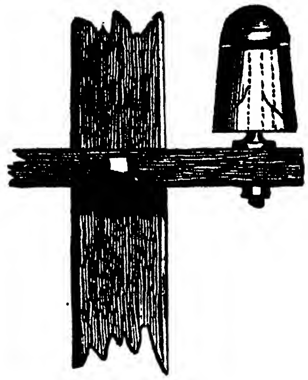


Fig. 4.

Frequently, especially in lines supported on buildings, the wire is fixed to every insulator, instead of merely resting in a loop, and then there is less need of stretching-insulators. The importance of careful insulation is very great, especially in long lines, as a very trifling loss at each point of support will soon seriously weaken the current, and render much more battery power necessary to transmit the message.

Copper wire is the best conductor by far, and might therefore be used of much smaller size than the iron wire usually employed. This would probably cause a considerable ultimate saving, as the posts and insulators need not be so strong; but the value of the wire would render it so strong a temptation, that the lines would not unfrequently be cut. From this and other causes iron wire is always employed. For general purposes that known as No. 8 gauge is used, its diameter being 0·170 inch, and its breaking weight about 16 cwt. Unless, however, the wire be protected in some way it soon rusts, and becomes corroded by the influence of the air and moisture. Sometimes it is coated with tar or boiled linseed oil. More frequently, however, in this country, the wire is "galvanised," or coated with metallic zinc, and this serves as a very good protection, except in the neighbourhood of manufacturing towns, where the smoke from the various factories soon corrodes away the zinc. In some cases, instead of a single wire, a strand composed of seven wires of No. 20 gauge is used, and this is by many considered preferable.

COLOUR.—I.

By A. H. Church, M.A., Professor of Chemistry, Royal Academy, London.

INTRODUCTION—CONNECTION OF THE SCIENCE OF OPTICS WITH COLOUR.

Owing to the dependence of colour upon light we must begin our study of its laws and their applications by a statement of two or three of the chief facts of Optics. We wish now to direct our readers' attention to the reflection, emission, transmission, absorption, refraction, and dispersion of light.

Everything that we can see is visible owing to its reflection of light, or to its emission of it: the former action produces or characterises illuminated bodies; the latter, luminous bodies. Illuminated bodies are marked out and distinguished from one another by the different amounts and qualities of the light which they reflect. A piece of black cloth on a white porcelain plate reflects but a very small part of the light which falls upon it; the plate, on the other hand, reflects much. Had the black cloth possessed no power of reflecting light, it would have been invisible; black velvet, which reflects less light, sometimes produces to the eye the effect of absolute blackness, that is, of an empty and dark space. Similarly, a sheet of plate glass may appear lustrous and visible enough if the light which falls on it is sent back to the eye; but if we are so placed in front of the glass that these rays escape us, it ceases to be visible, and we may, perchance, stretch out our hand to take something from behind the glass, wholly unconscious of its existence. But it is possible to render a piece of polished glass

permanently visible. Crush it to powder, and then in whatever direction the light falls upon its particles the surfaces of those particles will turn back or reflect some of the rays, and so render themselves visible. The clear glass has become opaque.

For the very same reason dense clouds, which appear black when between the observer's eye and the sky, owing to the complete way in which they cut off the light, may become brilliantly white when the sun's rays fall upon their constituent particles, owing to the very same action; for the light, which cannot get through the cloud, is continually reflected to and fro from the surfaces of its minute parts, and thus illuminates it. Thus it happens that the lower half of a cloud against a dark mountain may appear white, while the upper part of the same cloud against a luminous sky may appear a dull grey. The lessening of reflection, on the other hand, diminishes visibility. The numerous small reflections which occur between the surfaces of the fibres in a piece of paper may be greatly reduced by wetting or oiling the paper, when it becomes less opaque and at the same time greyer and clearer: to this cause the transparency of tracing paper and tracing cloth is due.

We said above that bodies differ not only in the amount but in the quality of the light which they reflect. Now one of the chief differences as to quality of light is the difference of colour. Powdered vermilion reflects much light to the eye; this light, however, is chiefly red light, though there is some white light mixed with it. A stick of red sealing-wax shows in some positions a bar of white reflected light in the direction of its length, while in other positions we see only the red light reflected from the particles at its surface and a small depth below. Why this light happens to be red in the vermilion we shall discuss further on: we would only point out here that while the reflection from a polished surface is regular, that from a rough surface is irregular, and that from a coloured surface coloured. A polished plane metallic surface affords an example of the first kind of reflection, a piece of chalk of the second. So great is the difference in effect produced by regular reflection from that produced by irregular reflection, that if an illuminated polished body could be found which was wholly incapable of irregularly reflecting any part of the light falling upon it, that body would be invisible. We may, therefore, say that we discern bodies by the aid of the light which they reflect irregularly, or scatter; a perfectly regular reflection gives, on the contrary, an image of the source of light, not of the object illuminated. It is only light which is regularly reflected which can be shown to obey the great law of reflection, which is this:—The angle which an incident ray of light makes with a perpendicular to the reflecting surface, is equal to the angle which the reflected ray makes with that perpendicular; in other words, the angle of incidence and the angle of reflection are equal. Another law here to be mentioned is, that both the incident and the reflected rays of light are in the same plane, which is perpendicular to the reflecting surface. We shall have to refer to these laws of reflection, to reflection at varying angles and from different substances, and to the different kinds of reflection enumerated above, when we proceed to discuss the subject of Colour.

A few words may now be said on luminous bodies, or those which emit light. A candle flame, a glowing piece of charcoal, and the sun, are examples of luminous bodies. From these sources of light luminous rays are sent out; these rays are the lines in which the light is propagated; luminous pencils are bundles of such rays. From such luminous bodies as are near the eye the rays emitted are divergent, but the rays from the sun and distant bright bodies are practically parallel. Highly luminous bodies can only be clearly seen when much of the light which they emit is cut off by a special contrivance, such as a piece of smoked or dark-green glass. It is thus quite possible to see the form and changes of the coke-points of the electric lamp, intense as its light is.

The light emitted from bodies travels in straight lines, and causes the production of shadows. The form and sharpness of shadows are influenced not only by the shape and the relative size of the opaque body which casts the shadow, but by the form of the luminous body, the light of which is intercepted. A luminous point gives a sharply-defined shadow, while a luminous surface, on the other hand, gives a dark shadow surrounded by a paler and less definite one which goes by the name of a penumbra.

We have so far spoken of the reflection and of the emission of light: the transmission of light has now to be considered. Bodies are said to be *transparent* when they permit light freely to pass, so as to allow objects to be distinguished through them; *translucent*, when they allow light to pass less perfectly, and objects on the other side of them cannot be clearly discerned; *opaque*, when light is wholly cut off. But in reality no bodies are perfectly transparent or perfectly opaque. The most colourless and flawless polished glass cuts off some rays, while substances, such as metals, which are commonly considered quite opaque, become transparent when reduced to the form of thin leaves. The sun may be conveniently viewed through a glass thinly coated with silver, while the light transmitted by an ordinary piece of gold-leaf is grass-green.

In addition to this, it may be remarked that different transparent bodies permit the light to pass through them with more or less facility, but they also variously affect the light which finds its way into them. Suppose the case of water. A beam of light made up, we will suppose, of 1,000 rays, strikes the water perpendicularly; 18 rays will then be reflected towards the luminous source, while 982 will find their way through the water unchanged, unless the layer of water be of considerable thickness. Now introduce into the water a drop of some red solution; the light transmitted will be filtered light, the red solution having strained off some of the constituent rays and left the others. The intensity of the light and its quality will thus have been altered by transmission, just as they are by reflection. Colour, in fact, may be produced from white light, either by the absorption of some parts of the luminous rays and the reflection of others, or by the absorption of some parts and the transmission of others; but, as we shall point out presently, there are several other ways of producing colour without the intervention of an absorbent body.

Before, however, we can profitably study these ways, and the curious phenomenon of absorption itself, we must become acquainted with the main features of the theory of light. This theory is called the *undulatory* theory.

The undulatory theory supposes the existence, throughout all space and throughout all matter, of an infinitely thin, elastic medium called the luminiferous or light-bearing ether. It must be supposed that this ether is not only universally present, but present without break in its continuity. It exists in space, in all solids, liquids, and gases, and it cannot be excluded from what we call a vacuum. It can hardly be material in the sense in which the sixty-three elements of the chemist are material; but to account for the properties of light, we must presume the medium which conveys it to have some at least of the properties of matter. The movement of this ether is light. It undulates in waves, the undulations of the particles of the ether being across the direction in which the light is propagated. Light is supposed to originate in the following manner:—The particles or molecules which constitute a luminous body are in a state of disturbance, a state of intensely rapid motion. This motion of the molecules is communicated to the ether and sets it in vibration, and is propagated in all directions in the form of spherical waves. Reaching the retina, this fine motion of the ether excites vision and becomes sensible as light. With these statements of the main assumptions of the wave-theory of light before us, we shall be able to consider with exactness not only the absorption and refraction of light, but the several modes of the production of colour.

The waves of the ether are of different lengths; in pure white light, such as that emitted by the electric arc, waves of all lengths occur between the limits of about $\frac{1}{30000}$ of an inch on the one hand, and about $\frac{1}{60000}$ of an inch on the other hand. Now the colour of light is solely dependent upon the length of the wave. The longest wave that is perceived by the retina is the red wave, the shortest the violet. Longer waves than the red waves possess a high heating power; shorter waves than the violet, invisible to the eye, and with scarcely any action on the thermometer, are gifted with a great degree of chemical energy: they are called actinic. If we use the electric light, which is really a more perfect light than that of the sun, we shall find that it emits or causes undulations, the waves of which are of much wider differences as to length than those of the red and violet lights above mentioned. By means of various solutions we can absorb some of the rays: those of light can, for instance, be strained off, and those of heat and actinism trans-

mitted. The waves of certain lengths cannot undulate in a solution of iodine in carbon disulphide, they are arrested or quenched thereby. Such a solution, indeed, permits only the rays of dark heat to pass through it; but the undulations of this dark heat may be changed, and their wave-lengths may be diminished by allowing the invisible heat-rays to be concentrated in a focus and to fall upon a solid, infusible body. This solid will become hot and then luminous—heat has been changed into light. This passage of calorific into luminous rays is known as *calorescence*, and may be made so complete a change that all the colours of the rainbow may be thus obtained from a perfectly dark source of heat. But exactly the same sort of change may be effected with the invisible actinic rays, the wave-lengths of which are shorter even than those of light. By using a solution of blue vitriol in ammonia, dark rays of chemical energy may be transmitted and freed from the visible rays. Receive these dark rays upon a screen of fluor spar, or Canary glass, or solution of quinine sulphate, light and colour are produced. The wave-lengths of the actinic undulations have been increased; the invisible chemical rays have passed into visible luminous rays; this passage is called *fluorescence*. Another name for the change in wave-length which we have just described is *change in refrangibility*.

We will now proceed to describe the meaning of the expressions *refraction* and *refrangibility*.

When a beam of light falls perpendicularly upon water, more than 98 per cent. of the rays pursue a straight course through the water. Let the incidence of the beam be oblique, and then it will be found that fewer rays will penetrate the surface, and that those which do will not pass through the water in a straight line, but will be more or less bent out of that line: this bending is called *refraction*. Refraction takes place when a beam of light passes obliquely from a rarer to a denser medium, or *vice versâ*. Instances of refraction have been already alluded to and described in THE POPULAR EDUCATOR (see "Recreative Science," Vol. IV., p. 305). It is owing to refraction that a stick half immersed in water appears broken; and for the same reason a coin, lying invisible at the bottom of a basin, may be made to appear by pouring water upon it, and so bending back the rays, which are reflected by the coin, till they reach the eye. In passing from air into water or glass the refracted ray is bent towards the perpendicular; in passing out of water or glass into air the reverse refraction occurs, and to a precisely equivalent extent. If, therefore, a beam of light enters obliquely a piece of glass, the faces of which are parallel, the refraction towards the perpendicular on entering the glass will be exactly compensated by the refraction from the perpendicular on leaving the lower surface, and so the emergent ray will necessarily be parallel with the incident ray. But supposing we employ a prism of glass instead of a flat plate, then the ray is permanently refracted. The prism so much employed in Optics is a wedge-shaped piece of flint glass, and is an indispensable instrument in the study of colour. The angle enclosed by two oblique sides of this prism is called the refracting angle. If we place the prism so that this angle shall be below, and the opposite side of the prism horizontal, then a beam of light falling from above on to one of the oblique sides will be refracted towards the refracting angle, and passing across to the other oblique side will pass out, with its path changed again, but now in an upward direction. But something more will have commonly happened to the beam besides its permanent refraction. If the light be simple, if its wave-lengths be of one measure only, it will be simply deflected; but if, as is nearly always the case, the light be compound—if its waves are of different lengths—then the prism will differently affect them. It will retard the short waves more than the long ones, and so we shall find that these short waves are more refracted. The more refrangible rays are then the short violet rays, the less refrangible rays are the longer red rays. In every case, therefore, where a luminous body emits rays of various refrangibilities, these rays can be separated from each other by means of the prism. As solar light consists of an enormous number of rays of different refrangibilities, it may be decomposed, analysed, or split into an enormous number of coloured lights, the wave-length of each of which belongs to a particular ray. The electric light gives an infinite number of such coloured lights, for there are no breaks in its series of rays, such as exist in the light of the sun. Burning metals and glowing gases emit, on the other hand, fewer rays, and give fewer colours, when their light is prismatically decomposed. The decomposition, or splitting up of light by the prism, is called the *dispersion* of light; the coloured image formed is called a *spectrum*. We are enabled to study the origin, the properties, and the changes of colours by means of this spectrum.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—I.

IT is intended in the present course of lessons to show the practical application of Geometry to trade and manufactures, in order to give to students engaged in the several constructive arts, and the various branches of industry involving skilled labour, a thorough and practical knowledge of the methods of describing the various figures required, by the most ready and correct processes.

It is impossible to over-estimate the importance of a knowledge of Geometry, forming as it does the basis of all mechanical and decorative arts, constituting, in fact, the grand highway from which the various branches of Drawing diverge.

Nor must the study of Practical Geometry be estimated by its mechanical value only, for its uses extend far beyond the necessities of trade and manufactures. It gives to the eye that absolute correctness of perception, that clear idea of form and size, which, as branches of education, render it most important to all; and, further, it will be found that it gives to the mind that habit of accurate arrangement, that order in mental processes, which must act beneficially on all persons, whatever may be their position.

In the present course, it is not proposed to give more of the definitions or elementary figures than may be absolutely necessary, the object being to apply *knowledge* to *practice*. Still the lessons will, as far as possible, be made self-explanatory, and the methods of drawing figures will be thoroughly explained.

The subject, then, is not to be treated as a mathematical, but as a thoroughly practical one, and therefore no absolute system of reasoning is attempted. Still, it has been thought right to give some simple and familiar explanations of the properties of the various figures, and the principles upon which their constructions are based, as it must be obvious that the more the mind comprehends of the relation cf one line and form to another, the more will the eye appreciate beauty and refinement, and the more accurately and intelligently will the hand execute.

In order to guide students in using these lessons for self-instruction, the processes in each figure are lettered in the order of the alphabet; the consecutive steps by which the result is attained will thus become evident. This plan is assisted by the imaginary or constructive portions being drawn in dots, or fine lines, the given figures in medium, and the resultant forms in full black lines.

The lessons are intended, therefore, as stepping-stones to Technical Drawing in all its branches, and it is hoped that by their means the artisan may be enabled to construct the forms required in his trade by rapid and certain means, instead of blindly following the traditional methods existing amongst the men in "the shop;" and it is hoped that when he has thus become acquainted with the "grammar of form," he may be able himself to originate and invent, and so be able to keep pace with the progress made, not only in foreign countries but in our own.

We commence, then, with certain figures constantly used in mechanical drawing, repeating such of the early studies as may be required in any particular figure, thus avoiding reference to back numbers as much as possible. The student is, however, supposed to have mastered such problems as bisecting lines, etc., and if he has not done so he will find them thoroughly explained in the "Lessons in Geometry" in THE POPULAR EDUCATOR.

One of the most frequently occurring processes is that of dividing lines into a certain number of equal parts. The want of knowledge of rapid methods causes waste of time, and by constant trials the paper becomes frayed and roughened, to the great detriment of the drawing. The following figure and its application is therefore given:—

To divide the line A B *into any number of equal parts* (in this case ten). (Fig. 1.)

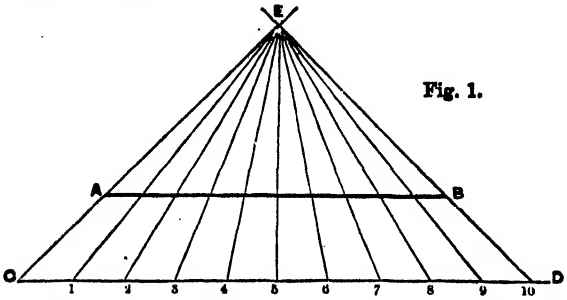


Fig. 1.

Draw a line (C D) parallel to A B. (The line C D may be any length, that is, it may be drawn indefinitely for the present.)

From C set off along this line the number of parts into which the line A B is to be divided—viz., 1 to 10. These parts may be *any* convenient size, but must be all equal.

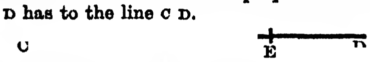
Draw C A and 10 B, and produce* both lines until they meet in E.

From each of the points 1, 2, 3, etc., draw lines to the point E, which passing through A B will divide it into 10 equal parts.

Application No. 1 *of the foregoing figure* (Fig. 2).

This problem may also be used for dividing a line proportionally to another, that is, to find divisions on a line, which shall be in the same proportion to it, that certain divisions are to another line either larger or smaller.

Thus, let it be required to cut off from a part which shall have the same proportion to it that the division E D has to the line C D.



Place A B parallel to C D, as in Fig. 2.

Join C A and D B, and produce the lines until they meet in F.

From E draw E F, which passing through A B will cut off G B, which will have the same proportion to A B that E D has to C D.

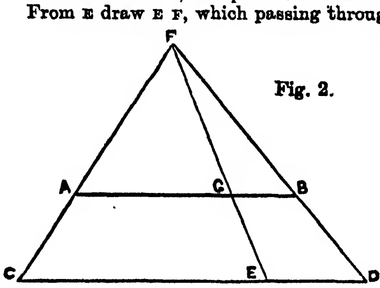


Fig. 2.

This process is constantly used in finding the proportions mouldings, windows, mechanical details, etc., in making reduced or enlarged drawings.

This problem is also most useful in finding a particular point in a line which may be so small as to render accurate division very difficult.

Example: The length from A to B in a spur† wheel (Fig. 3), including a *tooth* and a *space*, is called the *pitch*, and the circle on which such distances are set off is called the *pitch circle*.

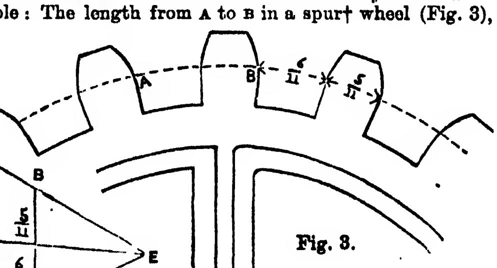


Fig. 3.

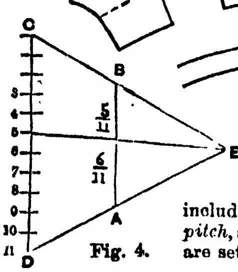


Fig. 4.

Now although in many drawings the space and tooth are made equal, they are not so in a real spur wheel, the space being a very little larger than the tooth. This small difference is most important, for if the tooth and space were equal, the tooth of a wheel when in gear with another would not clear itself. The difference of one-eleventh is found in practice to be sufficient for all purposes. Thus, if the "pitch" is divided into eleven equal parts, the tooth will be five-elevenths, and the space six-elevenths.

But dividing the space A B (which in many cases is much smaller than as given above) will be found liable to some inaccuracy: by this problem, however, the required point of division may be found with ease and exactness.

Let A B (Fig. 4) be the length of the pitch, measured from A B in Fig. 3. Draw any line, C D, parallel to A B, and set off on it 11 equal divisions (*any* length).

Draw C B and D A, and produce the lines to meet in E.

From point 5 draw a line to E, which will divide A B as required, the one part being $\frac{5}{11}$ and the other $\frac{6}{11}$.

Set off these lengths on the pitch circle.*

To construct an equilateral triangle on the given line A B (Fig. 5).

From A, with radius A B, describe an arc.

From B, with the same radius, describe a corresponding arc, cutting the former one in C.

Lines joining A C and B C will complete the triangle, which will be equilateral, that is, all its sides will be equal.

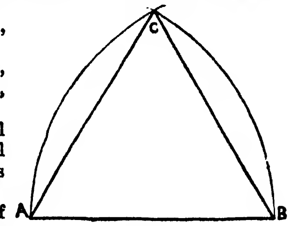
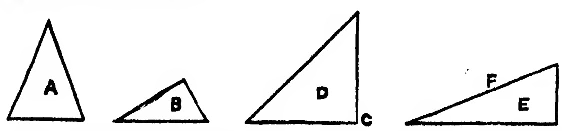


Fig. 5.

A triangle having only two of its sides equal, is called an *isosceles triangle* (A).

When all three sides are of unequal length, the figure is called a *scalene triangle*, as B.



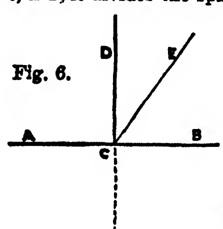
In a right-angled triangle, one of the angles, as C, is a right angle.

A right-angled triangle may be either isosceles, as D, or scalene, as E.

The longest side of a right-angled triangle, viz., the side opposite to the right angle, viz., F, is called the *hypothenuse*.

When a line, C D (Fig. 6), stands perpendicularly on another line, A B, it divides the space into two right angles; if produced

Fig. 6.



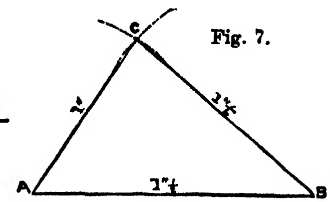


Fig. 7.

beyond C, four right angles will be formed; but if the line C E be drawn, dividing the space unequally, the angle A C E is an obtuse (or wide) angle, being *more* than a right angle, and the remaining portion, B C E, is an acute (or sharp) angle, being less than a right angle.

To construct a triangle of given dimensions (Fig. 7).

Let it be required that the sides of the triangle should be 1½", 1", and 1¼". (The sign" attached to a number denotes inches.)

Make A B 1½ in. long. From B, with a radius of 1¼ in., describe an arc. From A, with a radius of 1 in., describe an arc cutting the former one in C. Draw A C and B C, which will complete the triangle of the required dimensions.

* To "produce" a line means to carry it on further, or to make it longer in the same direction.

† A spur wheel is one in which the teeth are of iron, cast or cut in the rim; a cog wheel has wooden teeth mortised into the iron rim, and is used principally in mill-work.

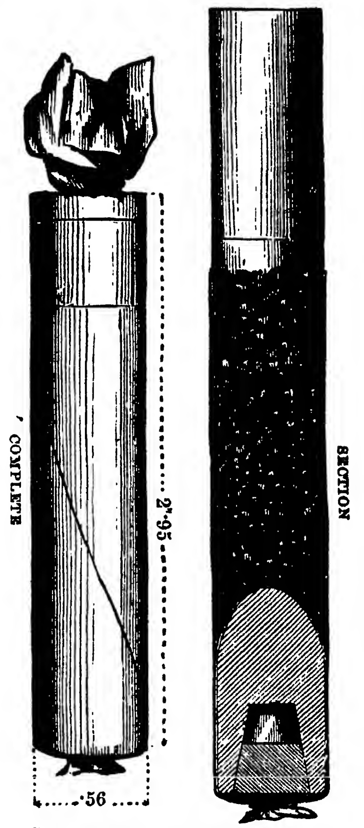
* For full instruction concerning the modes of drawing the various forms of teeth of wheels, the student is referred to the lessons on Technical Drawing.

WEAPONS OF WAR.—II.

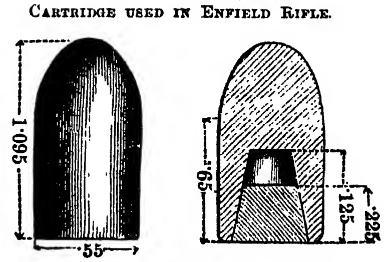
BY AN OFFICER OF THE ROYAL ARTILLERY.

FIRE-ARMS.

THE division of our subject which we have now to consider is the important one of fire-arms. We have seen how the introduction of fire-arms has had the effect of pushing side-arms into the background, how each successive development of fire-arms has by so much reduced the practical value of swords, and spears, and lances, and the like. We have noted also that the tide of improvement has always set in the direction of increased range, increased accuracy, increased destructiveness, increased rapidity of fire. These are the elements of the problem which the gun-maker has for several centuries been striving to solve, checked, however, and circumscribed in his action by the practical considerations which military necessities impose. Thus the exquisitely accurate match-shooting rifles which we see at Wimbledon, with all their refinements for ensuring good shooting—the carefully weighed charges, each in separate bottles, the delicate sights, the light triggers, have never come in for military use, because they fail in the first element of a military arm—simplicity. Again, the far-reaching Metford rifle, with which good practice has been made at 2,000 yards, could not become a military weapon because of its refinements, and because of its weight, and of the heavy charge which it requires. Many of the ingenious breech-loaders, in the production of which unhappy inventors have spent their time, their brains, and their money, fail altogether — despite their points of excellence and rapidity of fire—to satisfy the simpler wants of the soldier. But although let and hindered by these considerations—although constantly being turned back from the dazzling path of ideal excellence, and warned out of the dangerous byeways of theoretical refinements—although continually being reminded of the necessity of keeping to the somewhat tame and dusty high-road on which the soldiers are soberly tramping —a road which to some probably appears as straight and dull as those famous military roads of the Romans—despite these restrictions, the gunmaker manages to make very considerable advance in the direction required.



CARTRIDGE USED IN ENFIELD RIFLE.



BULLET USED IN ENFIELD RIFLE.

For many years the arm of the British soldier was a smooth-bore musket, familiarly known as "Brown Bess." This arm had a barrel of about three-quarter inch diameter (·753 in.), and threw a spherical leaden ball, which weighed 483 grains, with a charge of four and a-half drams of powder. It will easily be understood that such an arm was neither accurate nor far-reaching. The charge of powder was large enough, it is true, to project the bullet with a high velocity, but the size of the bullet caused it to meet with great resistance from the air, and thus soon to lose its velocity, besides being liable to be easily deflected. Moreover, being fired from a smooth-bore barrel, it was subject to all the disturbing causes common to smooth-bore projectiles. Among these causes may be named:—(1) windage, which is the difference between the diameter of the bullet and that of the bore, and which, by allowing the passage of the gas over the bullet, causes it to proceed through the bore with a sort of bounding motion, and to leave it in an accidental direction, according to the position of the last impact against the sides of the barrel; (2) irregularity of form and surface of the projectile; and (3) eccentricity of projectile. The result of these accumulated defects was that Brown Bess, although it would range effectively up to about 200 yards, could hardly be depended upon for even approximate accuracy up to half that distance. There used to be a saying among soldiers that if you fired at the church, you might think yourself lucky if you hit the parish! The smooth-bore musket was long retained in the Indian army, but was duly replaced by the Snider rifle, a converted Enfield. This weapon requires special ammunition, which might prove advantageous in the case of another outbreak. Some of the native Indian police have also smooth-bore carbines; and some of our coast-guard are still armed with smooth-bore pistols. Indeed, in some distant colonies we believe that even "Brown Bess" herself may still be found to this day.

After Messrs. Minié and Delvigne had shown how, by the adoption of a conical expanding bullet, an effective military rifle might be made, several of the old smooth-bore muskets were rifled with three grooves, and re-issued as rifled muskets—chiefly for naval use. By this means the weight of the bullet was increased to 825 grains, and the range, accuracy, and effective power of the arm were immensely improved. Compared with Brown Bess plain, Brown Bess rifled was an excellent weapon; although in these days of small bores we should smile at a bullet three-quarters of an inch in diameter. The first rifled arm possessed by the British soldier was the Brunswick rifle. This arm had two grooves, and fired a belted ball, which was covered with a patch, the grease upon which, according to Mr. Kaye, went far to determine the outbreak of the Indian mutiny. The bullet weighed 555 grains. The loading was tedious and inconvenient, owing to the belt on the ball having to be carefully adjusted in the groove, and to the great amount of friction in ramming home; and the weapon, although vastly superior in range and accuracy to the smooth-bore, was comparatively inefficient as a rifled arm. Our rifle regiments and sharpshooters were armed with it. The Sikh regiments in India were for a good while armed with the Brunswick rifle.

But the really important improvement in military fire-arms was due to the labours of Messrs. Minié and Delvigne. We by no means wish to underrate the exertions of other workers in the same field; and prominent among those who laboured to bring into notice the principle upon which the success of Messrs. Minié and Delvigne depended, was Captain Norton, who unquestionably invented and exhibited at Woolwich, as far back as 1823, an elongated expanding shot and shell, identical in principle with the Minié bullet. But it was not until 1851 that the Minié rifle was introduced. The arm was rifled with four grooves, and was intended to fire a conical leaden ball with a hollow in the base, into which was fitted an iron cup. The object of this arrangement was to enable the bullet to be readily loaded, the diameter being less than that of the bore, while by the action of discharge the iron cup would be driven forward into the conical hollow, expanding the bullet. A French colonel named Thouvenin had tried to accomplish the same object in a different way. He placed a small iron pillar or *tige* at the bottom of the bore, and on to this the bullet was rammed until it was expanded. The *carabine à tige* was used by the Chasseurs d'Afrique in 1846 in Algeria, but it was obviously open to some strong objections, such as the liability of the *tige* to become bent or broken, the delay in loading, the want of uniformity in expansion, and the disfigurement of the bullet. The

Delvigne-Minié system was a great improvement on this. The loading was effected almost as easily and rapidly as in a smooth-bore; and the expansion of the bullet depended not upon the exact amount of force or hammering given to it by the soldier, but upon the pressure exerted upon the iron cup by the powder gases at the moment of discharge. The arm as at first introduced was, however, open to some practical objections. In the first place, the iron cup was found liable in some instances to be blown through the bullet, which was left a distorted cylinder of lead inside the barrel, the weapon being thus rendered for the time unserviceable. In the next place, the calibre was too large for accurate long-range shooting—viz., ·702 inch. The weight of the bullet was also objectionably great from a military point of view, being 670 grains. With so heavy a bullet the soldier, if provided with a sufficient supply of ammunition, was inconveniently over-burdened. So, in 1853, a modified Minié rifle was introduced, with a bore of only ·577 inch, and three grooves, which fired a bullet of 530 grains with 70 grains of powder. The iron cup was replaced by a box-wood plug. The reduction in the weight of the arm with sixty rounds of ammunition was three pounds. This was the famous Enfield rifle—the weapon which won Alma and Inkermann, and which at this moment, under the name of the Snider rifle in its converted breech-loading condition, is the arm of the greater part of our yeomanry and auxiliary forces. But, since the introduction of the Enfield rifle in 1853, several improvements were successively made in the ammunition, which greatly increased the efficiency of the weapon. The two most important of these improvements were, the substitution of bees'-wax for a mixture of bees'-wax and tallow, for the lubricating material; and the reduction in the diameter of the bullet. Both these changes were suggested by Col. (afterwards Major-General) Boxer, and contributed in an important degree to the efficiency of the ammunition and the arm. The adoption of bees'-wax was recommended on the ground that in hot climates the tallow melted, leaving the rifle unlubricated, besides which the acid in the tallow caused the corrosion of the bullets. The wisdom of adopting pure bees'-wax was stoutly disputed at the time, and has been frequently disputed since. But repeated experiments and inquiries have fully established the efficiency of bees'-wax, and in the advertisement which was issued to the competing gun-makers in 1866, it was laid down that "wax on the bullets is indispensable;" and according to the evidence upon this subject taken by a committee on small-arms, the members were led to lay down that "the lubrications should be pure bees'-wax, as best adapted to withstand variations of climate and long keeping." This is a point upon which it seems important to insist. Inventors of ammunition are very fond of submitting fancy lubrications of their own, and it is well, therefore, that it should be distinctly understood that the question of lubrication for military small-arm ammunition has been most fully and patiently considered, and decided definitively in favour of pure bees'-wax. In the Royal Laboratory at Woolwich, the greatest care is taken to ensure the perfect purity of the bees'-wax, which is all subjected to a careful chemical examination.

The second important change which was made in the ammunition was in the reduction of the diameter of the bullet. It was found in India, during the mutiny, that great difficulties occurred in loading, owing to the size of the bullet, which was at first fixed at ·568 inch, leaving a windage of only ·009 inch—quite insufficient, when the rifle became foul, to admit of easy loading. Many instances occurred in which loading was almost impossible. The men were seen striking the ends of their ram-rods against walls and trees, to drive home the bullet, and the evil was so serious as to have threatened at one time to lead to the abandonment of the Enfield rifle. But some experiments, which were carried out by Colonel Boxer, showed that it was possible to reduce the diameter of the bullet considerably without affecting the accuracy of shooting. He found that a reduction of diameter from 0·568 inch to ·55 inch (giving a windage of ·022 inch) might be safely made, and the loading difficulty was thus completely overcome. Other minor changes were made, such, for example, as the addition of a cut through the paper surrounding the bullet, in order to cause the paper to free itself readily from the bullet in flight; the adoption of an improved powder, more uniform in its action, and better adapted to secure the just expansion of the bullet; the substitution of a baked clay plug for one of box-wood, which, as before stated, has superseded the iron cup of the original Minié. The iron cup was given up because it was liable to be blown through the bullet; the box-wood plug was given up on account of the cost of box-wood; and the clay plug was adopted as being inexpensive and efficient. The part which the plug plays in the action of the bullet must be noticed. It is generally spoken of as the expanding agent. This is true to a certain extent; but the expansion can also be secured without any plug. In the Pritchett bullet, for example, which for some short time was used with the Enfield rifle, there is only a shallow hollow, and the expansion is due partly to the action of the gas within this hollow, and partly to the "upsetting" of the bullet, which is due to its inertia. Other bullets—the Whitworth, for example—depend entirely upon the "upsetting" or "over-taking" action. But the plug serves a further and important purpose. It is a supporting as well as an expanding agent. The Pritchett bullet was found to foul, for the simple reasons that the expansion was not so promptly effected as in a plugged bullet, and thus a rush of gas over the bullet became possible, and that when the barrel had become foul, the expanded sides of the bullet, having no internal support, collapsed on coming into contact with the fouling deposit. The plug, therefore, serves a threefold purpose:—1. It ensures the expansion. 2. It makes that expansion so prompt and rapid that the chance of an escape of gas over the bullet is diminished. 3. It supports the expanded sides when the rifle has become foul.

The construction of the Enfield rifle cartridge is shown in the illustrations in the preceding page. It consists of a hollow rolled cylinder of paper, or rather a double cylinder, since the part which contains the powder is a separate cylinder contained in the outer envelope, by which the bullet is attached.

The lubrication is applied on the outside of the paper which surrounds the bullet—up to the shoulder of the bullet—which is loaded with the paper upon it, the top of the cartridge being first torn off, the powder poured into the barrel, the papered bullet inserted in the muzzle, the rest of the cartridge being torn off and thrown away, and the bullet rammed home. The ease of loading with the ·55-inch bullet is so great, that in a clean arm it is possible to load without the ramrod, by striking the butt against the ground.

The bullets are made of perfectly pure lead, the purity of which is tested by chemical analysis. Any impurity tends to alter the weight and to affect the expansion, and thus to spoil the shooting of the arm. The bullets are all made by compression—the lead being first squirted into long rods—and then formed into bullets in a machine, which is one of the sights of Woolwich Arsenal. The weight of each bullet, with the plug, is 530 grains; and the accuracy of manufacture is so great that the working limits are only two grains over and under the mean weight. The charge of powder is seventy grains. The Enfield rifle is capable of shooting with great accuracy up to about 800 yards, and good practice has been made with it occasionally at longer distances. But 800 yards may practically be regarded as the extreme limit of accuracy of a bore so large as ·577 inch, unless the weights of bullet and powder were unlimited, which, in view of the soldier's requirements, of the quantity of ammunition which he has to carry, and of the amount of "kick" or recoil which he can endure, they cannot be. We have omitted to mention that the pitch of rifling of the Enfield is one turn in six feet six inches; the grooves are ·235 inch wide, and ·005 inch deep at the muzzle, and ·013 inch deep at the breech. The weight of the arm is as nearly as possible nine pounds. The weight of sixty rounds, packed for service, with the proportion of ninety caps, is about five pounds eleven ounces. The same ammunition is used with all muzzle-loading rifled muskets of ·577 bore. A similar cartridge—differing only in the weight of the charge of powder, which is reduced to two drams—is used with all muzzle-loading carbines of ·577 bore. The carbines and the short rifles are for the most part rifled with five grooves, and a pitch of one turn in forty-eight inches. This disposition of rifling is more favourable to accuracy than the three grooves and slow pitch. Some oval-bore Lancaster rifles having no grooves were also used by the engineers. The bore is oval, and the oval being disposed spirally along the barrel gives the necessary spin to the bullet. The oval is at muzzle, major axis = ·593 inch; minor axis = ·577 inch. At breech, major axis = ·598 inch; minor axis = ·580 inch. The same ammunition is used with the Lancaster as with the Enfield rifle. The shooting of the Lancaster is, however, decidedly superior.

MINERAL COMMERCIAL PRODUCTS.—IV.

II.—MINERALS PROPER.

COAL.

COAL is a mineral substance very generally diffused throughout the earth's surface; it occurs of different geological ages in various parts of the world, but by far the greater proportion of valuable workable coal is derived from the Carboniferous series of formations. Good workable coals are obtained in the Lias and Oolite; brown coals and lignites are of Tertiary age. Coal consists of vast collections of carbonised vegetable matter, impregnated in varying degrees with the pitchy and resinous substances now so characteristic of the fir family. Peat bogs in superficial beds present perhaps the first stage in such a change. These masses of vegetable matter, though containing much water, can be made available for house fuel, fuel for manufacture, very fair charcoal, and for the extraction of naphtha, paraffin, tar, etc. In the presence of an abundant supply of coal, peat cannot be economically employed, but it is extremely useful where coal is scarce, as in Holland, many parts of France, Germany, and Ireland. A nearer approach to true coal is the lignite, woody, or brown coal. This mineralised vegetable product, like peat, contains a considerable quantity of moisture, and it suffers in quality on exposure to the air. It is a Tertiary deposit, and is found in Breslau, on the Rhine, in Germany, on the Danube, and the shores of the Baltic, in Styria, Tuscany, Nova Scotia, New Zealand, Devonshire, and County Antrim. True coal is very compact, has for the most part lost its woody and fibrous character, and contains a very small quantity of earthy matter. It consists of two principal varieties, the bituminous and the anthracitic. Bituminous coal contains a large proportion of gas, tar, paraffin, and such substances, and burns, therefore, with a brilliant flame. It is, hence, peculiarly adapted for domestic consumption, for gas, for manufactures, coke, etc. The bituminous coal richest in volatile constituents is the variety called "Cannel"—in Scotland the "Parrot"—which burns with great brilliancy. Other varieties are splint and cubic coals. A semi-bituminous coal, burning with less brilliancy and rapidity, but affording great heat, is called "steam coal," from its use in furnishing the supplies of steam-vessels taking long voyages. The middle part of the South Wales coal-field (the western is bituminous), and a part of the Newcastle field recently worked, contain excellent coal of this character.

Anthracite coal is very hard and glossy, not soiling the fingers. It is almost pure carbon, containing but a very small proportion of gaseous products. It burns with a very feeble flame, but gives an intense heat. From its comparative difficulty of combustion it was formerly but little used; but by the introduction of the hot-air blast, and other improvements in furnaces, it can be made available for many manufacturing processes, particularly that of the preparation of iron, for which it is now extensively used in Wales (the eastern part of the coal-field being anthracite) and the United States.

Notwithstanding the enormous consumption of this important fuel, the supply will, perhaps, *never* be exhausted. Immense areas in the New World must be added to the still profusely abundant districts of the Old. The coal area of Great Britain and Ireland amounts to thousands of square miles in extent; when we add to this the known deposits in the rest of Europe, in Asia, in America, Australia, and Africa, covering a surface of many hundred thousand square miles, we see how vain it is to anticipate the day when our fuel shall have been consumed.

The following table may not be devoid of interest in showing how the exports of coal from the United Kingdom have increased within recent years. The quantities in the second column include all the different kinds of coal, cinders, and culm, while the third column contains the declared value:—

Years.	Tons.	Dec. Value.	Years.	Tons.	Dec. Value.
1858	6,529,483	£3,045,434	1866	9,953,712	£5,102,805
1859	7,006,949	3,270,013	1880	18,719,971	
1860	7,321,832	3,316,281	1881	19,587,063	8,785,950
1861	7,855,115	3,604,790	1882	20,934,448	9,564,616
1862	8,301,852	3,750,867	1883	22,775,634	10,645,919
1863	8,275,212	3,713,798	1884		10,851,130
1864	8,809,908	4,165,773	1885	23,770,957	10,633,151
1865	9,170,477	4,427,177	1886		9,837,338

The average annual produce of the principal coal districts of the globe was in 1884 as follows:—

	Tons.		*Tons.*
Britain . .	160,757,779	Austro-Hungary	18,191,000
Germany . .	57,109,326	Russia . . .	18,000,000
France . .	20,127,209	India and Japan	3,000,000
United States	95,000,000	Australasia . .	3,478,863
Belgium . .	18,051,499	Canada . . .	1,600,000

BITUMINOUS SUBSTANCES.

Many bituminous substances are produced in vegetable matter during its conversion into coal; the chief of these are naphtha, petroleum, and asphalte, which are all hydro-carbons of varying proportions, and of an inflammable nature. The bituminous substances are widely distributed, especially in the tropical and sub-tropical regions—a circumstance which evidently indicates that the substances are due to extensively operating natural causes, and not, as usually supposed, to the accidental combination of special agencies.

The modes of occurrence of asphalte deposits seem referable to three principal divisions:—1. In the rocks of igneous origin; this is the case in Cuba, and at Mount Lebanon. 2. In stratified rocks of the Palæozoic and Mesozoic epochs, usually disseminated in a granular form throughout the entire stratum, or issuing from the soil, or exuding from fissures in the rocks, in the form of springs of petroleum, naphtha, etc. 3. In rocks of Tertiary age, usually accompanied by lignite or brown coal. These are the most abundant sources of asphaltic substances, and include those of Pegu, Trinidad, etc.

Naphtha is a transparent and nearly colourless fluid, burning with a copious flame and strong odour, and leaving no residuum.

Petroleum is dark-coloured, and thicker than common tar. It rises in immense quantities from some of our coal-beds, and impregnates the earth so as to form springs and wells. Petroleum springs contain a mixture of petroleum and the various substances allied to it: they occur in abundance in Modena and Parma, Italy, Persia, Canada, United States, etc., but the most powerful are those in the province of Pegu, in the Burman Empire. In many parts of the world petroleum is now the most abundant source of photogen and paraffin. The petroleum or rock-oil of the United States is refined for illuminating purposes, while in the crude state it is a good lubricant.

Bitumen, or *Asphalte*, is an inspissated mineral oil, of a dark-brown or black colour, with a strong odour of tar; the most valuable is hard, brittle, of a brilliant lustre, and eminently conchoidal fracture; a variety occurs of the consistency of jelly, and bearing some resemblance to soft india-rubber. It is very abundant on the shores of the Dead Sea, occupies the so-called pitch-lake in Trinidad, and occurs in Cuba, Peru, Mexico, Ionian Isles, Portugal, etc. The Rangoon tar or Burmese naphtha is distilled from a number of volatile hydro-carbons, chiefly used as lamp fuels; those known as Sherwoodole and Belmontine have considerable detergent power, removing stains from silk without impairing delicate colours. Beds of limestone and clay occur impregnated with bitumen, and from such paraffin is distilled in Britain, Germany, France, Austria, etc.

Jet, so much prized in the manufacture of ornaments for its intense blackness, its lightness, and its beautiful polish, is a variety of lignite highly bituminised and free from earthy impurities, and resembles Cannel coal, but it is blacker, and has a more brilliant lustre. It occurs in the Upper Lias of Whitby, in which it is very abundant, in Languedoc, Asturias, the Alps, Galicia, and Massachusetts. The jet manufacture of Whitby is a valuable industry.

Amber is a fossil resin, the origin of which has been traced to coniferous trees. It is found in alluvial gravels. It occurs too, in the Cretaceous marls of France and Germany. It is procured from Prussia, the shores of the Baltic, the Adriatic and Sicilian shores, and from Japan, Madagascar, and the Philippine Islands.

Gum Copal is a semi-fossilised gum found in a sandy soil in the hilly districts all along the coasts of Angola, the total yearly export of which from all the districts of Angola is estimated at 2,000,000 lb. A gum copal is obtained under similar conditions from Sierra Leone and Zanzibar, the origin of which, as well as that of Angola, is still unknown.

Some copal resins are exudations from living trees, as that furnished by *Guibortia copallifera* of Sierra Leone, and others.

TECHNICAL DRAWING.—V.

FREEHAND DRAWING (*continued*).

Agreeably with the plan already laid down, to practise freehand concurrently with linear drawing, the following figures are given as examples of objects which are so nearly flat that they can be rendered by their outlines only, without a knowledge of perspective, which the student has yet to acquire, and in which lessons will be given further on.

Fig. 25 represents a pair of compasses, such as are commonly used by joiners. In beginning this simple subject, draw a horizontal line, and on it erect the perpendicular A B.

From A set off A C and A D, and joining B C and B D, complete the triangle C B D.

The apex of this triangle will be the centre of the rivet. Draw the small circle around this point, and the larger circle for the head of the compasses.

Next draw the lines E C and F D, which form the outer sides of the instrument, and which are slightly curved. The inner sides to G and H are straight, and are portions of the triangle previously drawn. The lines I and J correspond with the outer edges, of which, indeed, they form portions when the compass is closed.

Fig. 26 is an outline of a shaping-knife, and but very few instructions will be required for copying it. Draw a horizontal line for the back of the tool, and two lines at right angles to it, which are to form the centre lines of the handles. The instructions given in relation to the handle of the screwdriver will serve for these as well; but you must be careful to get the two handles *precisely* alike. When this is accomplished, draw the edge of the blade parallel to the back, and then complete the curved portions by which the blade is united to the handle.

Fig. 27 is a drawing of a tool with which the carpenter will be well acquainted; but it often happens that although we may have seen a thing daily, we have never noticed the peculiarities in its form which may strike a casual observer.

This habit of observation is one of the beneficial results of mental training, and no instruction is so likely to induce it as drawing; for a man who accustoms himself to draw from objects, will, in the old-fashioned words, "walk through the world with his eyes open," and every day, nay, every hour, will add to his stock of information, and of his power of delineating the objects he sees. To workmen this is especially important, and practice in drawing tools will be both interesting and useful.

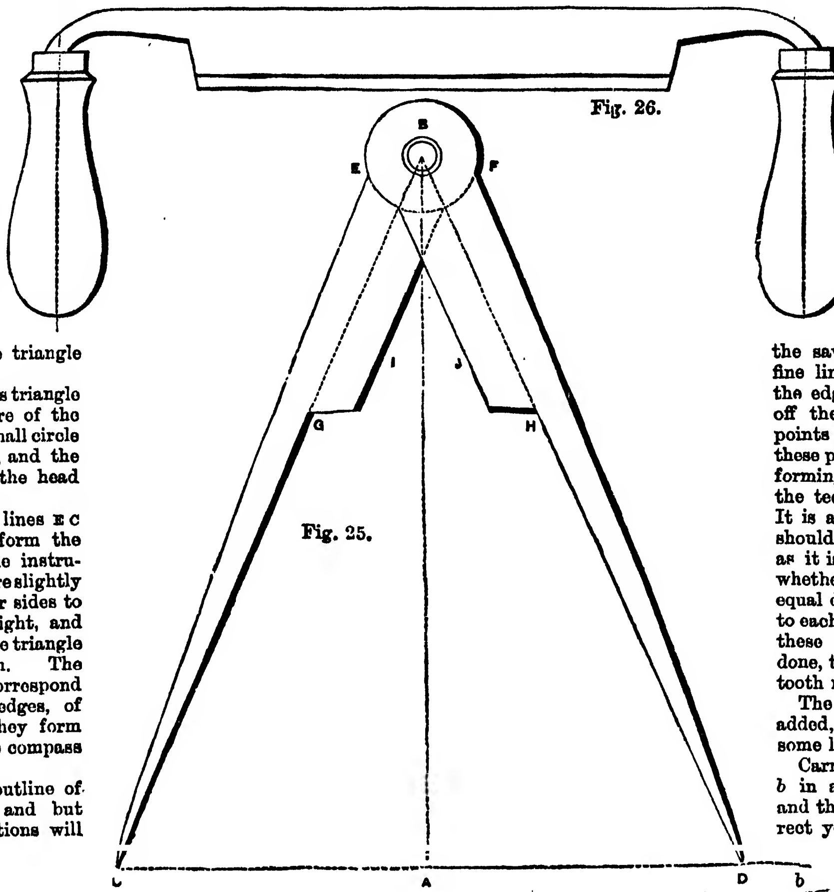


Fig. 26.

Fig. 25.

In the figure now before us, the long oblique line, *a b*, forming the back of the saw, is to be drawn first, and then *b c* at right angles to *a b*. At *a*, a short curve will lead to the line *d*, which is a continuation of the back; thence the line turns to *e*, forming the end of the saw. From *e* draw a fine line on which to rest the edge, and on this set off the distances of the points of the teeth; on these points the short lines forming the front edges of the teeth are to be drawn. It is advisable that these should all be drawn first, as it is then easier to see whether they are all at equal distances, or parallel to each other, or not. When these are satisfactorily done, the back line of each tooth may be drawn.

The handle must now be added, and this requires some little care.

Carry on the line from *b* in a curve downwards, and then the eye must direct you in following the form until you come to *g*. Returning to *f*, draw *f h*, and follow the curve to *i*; next, the under side of the handle, *i j*, then the curve *g j* will complete the external form of the handle.

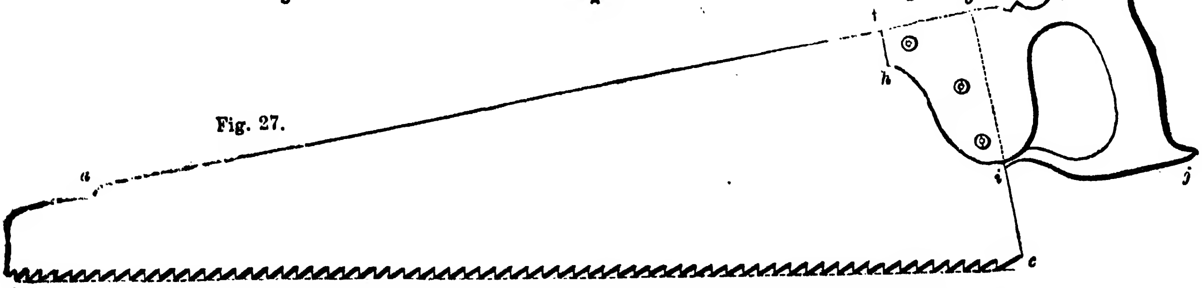


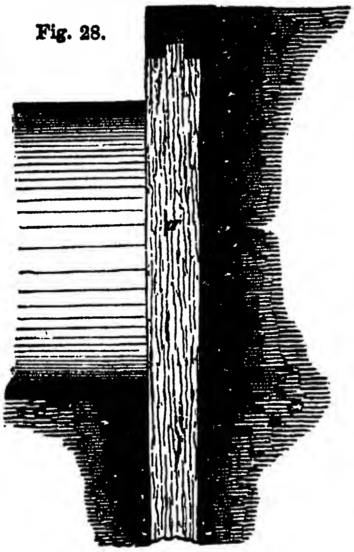
Fig. 27.

Now return to the point *i*, and carry the curve round so as to form the inside of the handle. The screws are to be drawn next, and no workman will require to be reminded that these must be placed *inside* the line *b c*; in fact, it was to make sure that the screws should be rightly placed that the whole line *b c* has been drawn, whilst only the portion *i c* is required.

Now, all saw-handles are not precisely alike, and further, their edges are bevelled off, so that at *f h i*, etc., double lines would

seen. All this is, however, omitted here, so as to keep the example as simple as possible. When, however, this is mastered, the student is advised to make a drawing *from his own saw*, and having sketched the general form as in the present figure, to fill in any detail he may observe.

Fig. 28.



But he should also attempt to draw it in some other position: for instance, hanging by the handle from a nail in the wall.

Whilst making such a sketch, the paper must be kept perfectly straight in front of the student; but when the form is completed, he should turn it so that it may be in the position of that in Fig. 27, and he will then possibly see many points requiring correction. Still, it is necessary that he should become accustomed to sketching objects in any position in which they may be placed, and this will soon be accomplished by practice and perseverance.

LINEAR DRAWING BY MEANS OF INSTRUMENTS (*continued*).

Fig. 28 is the section of a dam, or wall of planks, which confines the soil subject to the action of water. Of course, the strength required for such a dam must depend on the height of the water-level—that is, the wall must be strong in proportion to its height. Fig. 28 is one of the simplest examples of these constructions, and consists of piles, placed at a distance from each other, which must be regulated, first, by the nature of the soil at the back of the dam, and its tendency to press forward; and secondly, by the thickness of the planks employed for the wall, which must be such as to resist their being bent by the force of the soil they confine. Of course, the more such pressure is to be expected, the closer must the piles be placed.

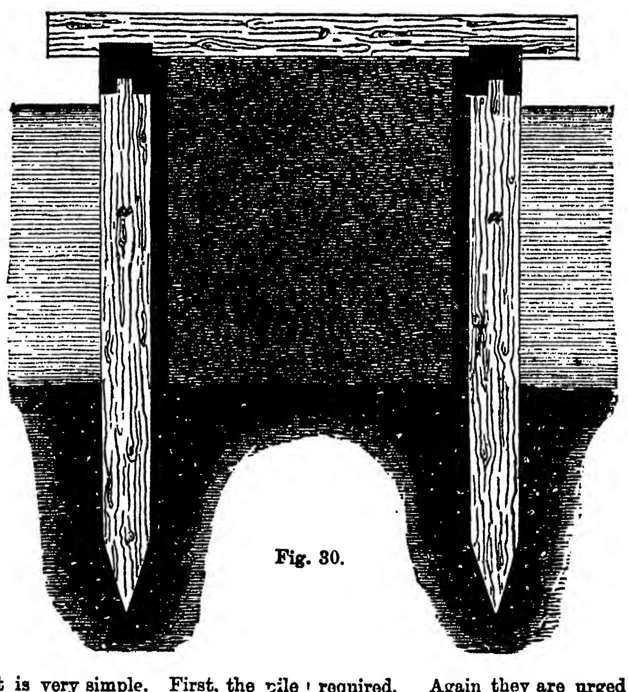


Fig. 30.

The piles are in the above example connected at the top by a cross-timber, into which they are mortised. The planks are then placed horizontally at the back of the piles, and may be united by the methods shown in previous lessons.

The drawing in this subject is very simple. First, the pile *a*, with section of the cross-beam *b*; next, a line parallel to the inner side of the pile, and at a distance from it equal to the thickness of the planks of which the wall is to be constructed; between these two lines short horizontals are to be drawn, or the joints of the edges shown, according to the method adopted.

Fig. 29 is the section of a dam used in cases where the soil is very swampy in character, or where the external water might pass through fissures in the bed of the stream, and so enter the foundation at a lower level than the bottom of the wall adopted in the previous case. The plan here adopted is to drive in the strong piles *a*, and to connect these by the cross-timber *b*, partially sunk and temporarily fastened on to them. Another timber, *d*, is then to be laid on the bed of the water, parallel to *b*, and this is also to be bolted on to the piles, and at the back of these the wall of perpendicular planks, united at their edge by one of the methods already shown; or sheet-piles, *c*, may be used—these are driven down far below the bed of the water, as the circumstances may require.

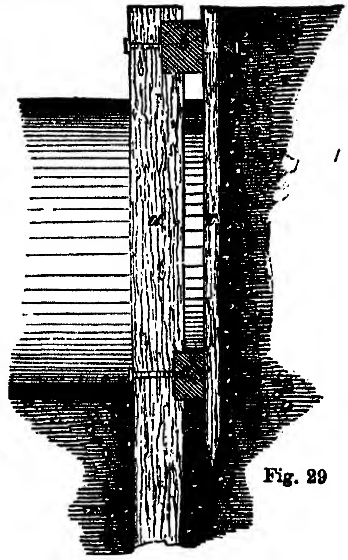


Fig. 29

Each of these planks having been driven until it reaches more solid soil, the strong rail, *e*, is placed at the back of them, and a bolt passing through *e*, *b*, and *a* binds them all firmly together; the heads of the planks are then sawn off to one level.

Fig. 30 is a section of one of the walls of a coffer-dam. A coffer-dam may be defined as a water-tight wall, enclosing the site on which the pile of a bridge or other structure surrounded by water is to be erected.

Coffer-dams are, of course, constructed of a strength sufficient to bear the pressure of the water from without, which would sometimes damage, or even demolish them altogether, were it not that they are secured by struts, and otherwise strengthened.

The coffer-dam, of which Fig. 30 is a section, is one of the simplest used; it consists of a double row of piles, *a*, *a*, united by the head-piece, *b*, the rows of piles being kept at equal distances from each other by cross-timbers, *c*, which, as will be seen in the illustration, act as a cramp in preventing them either spreading outward, or being pressed inward.

Walls of planks, *d*, *d*, are next attached to the inner sides of the piles, the internal space being then rammed with clay, etc.

In drawing this and the future examples, the students are reminded that they are arranged progressively, and that as the subjects increase in difficulty, additional care and accuracy are required. Again they are urged not to be content with their work being *nearly* right. To carpenters and joiners this accuracy is especially important, for the different parts, got out by separate workmen, must, when required, fit exactly to each other, and this would not be the case if either one of them had been careless or inaccurate. This exactitude is only to be obtained by accustoming yourself, from the very outset, to measure with care, and to draw your lines exactly through the proper points.

NOTABLE INVENTIONS AND INVENTORS.

II.—CLOCKS AND WATCHES.

The earliest recorded timepiece is the sun-dial of King Ahaz, who lived about B.C. 742. The first constructed on mathematical principles was placed at Rome, B.C. 293, until which period the heavenly bodies appear to have been the only measure of time known to the Romans. The most perfect sun-dial was, however, unavailable when the atmosphere was charged with clouds; hence the dropping of water, being nearly a regular motion, was, at a remote period, applied to the measurement of time. About the year B.C. 145, Ctesibius of Alexandria invented a clepsydra, and he is even said to have applied toothed wheels to water-clocks. In the year A.D. 800 the Caliph Haroun al Raschid presented to the Emperor Charlemagne a clepsydra of gilded bronze, which is stated to have performed many wonders, altogether incredible; it is, however, the first time-keeper which is recorded to have struck the hour. Alfred the Great, we are told, measured time by burning wax-candles marked with circular lines to indicate the hours; but these must have been imperfect time-keepers.

By whom was first invented the clock with wheels having a balance, it is hard to say; it was, however, originally called a *horologe*, the word clock (probably derived from the French *cloche*, a bell) being applied even so late as the fourteenth century to the bell which was rung to announce certain hours indicated by the sun-dial or clepsydra. The word *horologe* being formerly applied indiscriminately to a dial as well as a clock, nothing decisive can be inferred from its use. A method of making clocks without the assistance of water was known about the year 1129, and they were set up in churches as early as 1174. Towards the middle of the thirteenth century a Saracen is stated to have received a sum equal to £2,000 for having made a clock moved by weights. This machine was afterwards presented to Frederick II., Emperor of Germany.

The first author who has applied the term *horologe* to a clock appears to be Dante, who was born in 1265, and died in 1321. It would thus appear that striking clocks were known in Italy as early as the latter part of the thirteenth or beginning of the fourteenth century. In the reign of Henry VI. a pension was granted to the Dean and Chapter of St. Stephen's for taking charge of a clock placed in a turret in Palace Yard, opposite to Westminster Hall, which clock was the work of an English artist. It was erected in the time of Edward I., A.D. 1288, from a fine imposed on the Chief Justice of the King's Bench. This famous *clochard*, or bell-tower, was built in the reign of Edward III., 1365–6, and Henry VI. gave to the Dean the keeping of this clock, with 6d. per day, to be received at the Exchequer. About the same time a clock was placed in Canterbury Cathedral. Then we have an authentic account of one of the earliest astronomical clocks, a clock invented by Richard Wallingford, abbot of St. Albans, who, in 1326, had it placed in the monastery. It showed the hours, the apparent motion of the sun, the changes of the moon, the ebb and flow of the tide, etc. In the time of Henry VIII., Leland said, "All Europe could not produce such another." Wallingford's account of this clock is preserved in the Bodleian Library. When the inventor had finished this clock, so scarce was the knowledge of mechanics that he was obliged to compose a book of directions for managing and keeping the clock in order, lest it should be ruined by the ignorance of the attendants. The old clock in Wells Cathedral (removed from Glastonbury Abbey at the Reformation) was constructed about the year 1320, by Peter Lightfoot, a monk of Glastonbury: the dial showed the motions of the sun, moon, etc. On the top of the clock eight armed knights saluted each other with a rotatory motion.

In 1344, James Dondi, citizen of Padua, philosopher, physician, and astronomer, constructed for his native city a clock similar to Wallingford's; this obtained for him the name of Horologicus, and his family existed at Florence till our time, and bore his name. His son, John Dondi, made another clock for the city of Padua. About the same time one still more complicated was made for Padua by William Zealander. Clock-making also flourished in Germany, particularly at Nuremberg, about the beginning of the sixteenth century. The middle of the fourteenth century seems to afford the first certain evidence of what would be now called a clock, or regulated horological machine. There is a clock in Dover Castle, dated 1348; and there is in Peterborough Cathedral a clock still in use as to the striking parts, of which the combination is very like that of the Dover Castle clock. It is said that the first clock at Bologna was fixed up in 1358. Henry de Wyck, a German artist, placed a clock in the tower of the palace of Charles V., about 1364; Edward III. gave protection to three Dutch horologiers, who were invited from Delft into England in 1358; and this appears to have been the probable introduction of clockwork into England. The origin of the famous clock in Strasburg Cathedral dates from 1352: the artist's name is unknown, but the clock was a highly successful work of the art of the period. It was divided into three parts—a universal calendar, an astrolabe, and figures of three kings and the Virgin carved in wood. At the striking of each hour the three kings bowed to the Virgin, whilst a carillon played a cheerful tune, and a cock crowed and flapped its wings. This clock being out of order in 1547, its repair was entrusted to the charge of three mathematicians of high repute: they died before their work was finished, but it was taken up by a pupil of one of them, Count Dasypodius, who completed his task in four years. The clock went well until the year of the great revolution, when it struck for the last time. Nearly fifty years passed, when one Schwilgen, a mathematician of Strasburg, repaired and reinstated the clock, in four years, from June 24th, 1836, its mechanism was placed in the old case, the figures being increased and improved by jointed limbs. The quarter chimes are struck by four figures which move in a circle around a skeleton mower; the hour bell is struck by a figure of an angel turning an hour-glass, through which sand runs. Every day at noon there is a procession of the twelve apostles round a figure of the Saviour; the cock flutters his wings, opens his beak, and crows three times. The clock shows the month, the day of the month, the sign of the zodiac, the Dominical letter, the sidereal time, the Copernican planetary system, and the precession of the equinoxes; and its mechanism marks the 29th day of February in every leap year. The full mechanism is set in motion at noon only. Fortunately, this curious clock was not injured during the destructive siege of Strasburg by the Prussians in 1870, though the cathedral did not escape. Lehmann informs us of a clock at Spires with such mechanism in 1395. Nuremberg had a public clock in 1462. Auxerre had one in 1483, and Venice in 1497. The clock in the north tower of Exeter Cathedral has two dials, and its construction is referred to the reign of Edward III., when the science of astronomy was in its nonage, and the earth was universally regarded as the central point of the universe. The upper disc of this clock, which was added in 1780, shows the minutes. The hour disc is divided into three parts; the figure of the earth forming the nucleus of the innermost circle, that of the sun traversing the outer space, that of the moon the intermediate one. The sun is stamped with a fleur-de-lis, the upper end pointing to the hour of the day, the lower to the age of the moon; while the figure of the moon is made black on one side, and moved by the clockwork, so as to imitate the inconstant original.

In 1382, the Duke of Burgundy ordered to be taken away from the city of Courtray, on the entry of the French army, a clock which struck the hour, and which was the best at that time known; the Duke had it brought to Dijon, his capital, where it may be seen in the tower of Notre Dame. The cathedral clock at Lyons, dated 1385, was nearly as curious as the above. It resembled in its mechanism the Strasburg clock: two horsemen had a combat on the dial-plate; a door opened and displayed the Virgin Mary with Jesus Christ in her arms; the Magi, or Wise Men with their retinue, presented their gifts, headed by two trumpeters playing. *La Grosse Horloge* at Rouen is chiefly remarkable for its great size. The cathedral clock at Lunden, in Denmark, said to have been constructed in 1390, must have been copied from Lyons Cathedral clock; in the dial are seen the year, month, week, day, and hour of every day throughout the year, with the feasts movable and fixed, and motion of the sun and moon; the clock strikes by two horsemen in encounter giving as many blows as the bells sound hours; the Virgin Mary, enthroned with Christ in her arms, the Magi, etc., as are shown at Lyons. Lubeck Cathedral clock, date 1405, represents the changes of the heavenly bodies until 1875; when it strikes twelve, a number of automaton figures are set in motion; the Electors of Germany enter from

a small side door, and inaugurate the Emperor, who is seated upon a throne in front. Another door is then opened, and Christ appears, when, after receiving his benediction, the whole cavalcade retires amidst a flourish of trumpets by a choir of angels. On each side are bas-reliefs of passages in the life of our Saviour; in that of the Last Supper, a mouse is peeping from beneath the table-cloth—the *mouse* representing the armorial bearings of the once puissant Lubeck. The similarity of the above clocks has led to the supposition that they were constructed from a design under Papal authority, to cause wonderment in the people.

About 1525 the clock of St. Mary's, Oxford, was furnished out of fines imposed upon students of the University. In the middle or clock quadrangle of Hampton Court Palace, over the principal entrance, is, according to Dr. Derham, the oldest English-made clock extant, constructed in the year 1540, by a maker of the initials "N. O." This clock contains mechanism for representing the motions of some of the heavenly bodies. Copernicus was living at the time of its date, but more than a century elapsed after this time before the invention of the pendulum was applied as the regulator of clocks. These facts render the wheelwork of this ancient clock, and especially its celestial mechanism, very interesting. Dr. Derham, describing it in his "Artificial Clockmaker," 1714, states that the Hampton Court clock shows the time of day, and the motions of the sun and moon, through all the degrees of the zodiac, together with the days of the month, the sun and moon's place in the ecliptic, the moon's southing, etc. Langley Bradley repaired it in 1714, and it was again altered and repaired somewhere between 1760 and 1800. The astronomical furniture is incorrectly attributed to Thomas Tompion, the celebrated clockmaker, but he died in 1669, or about 129 years after its construction, though he might have been employed upon it (see Henderson's "Horology," pp. 16, 18, 2nd Edit. 1836). The dial, and part of the wheel attached to the back of the dial, still remain. About the year 1560, the Danish astronomer, Tycho Brahe, possessed four clocks, which indicated the hours, minutes, and seconds; the largest of these had only three wheels; one was about three feet in diameter, and had 1,200 teeth in it, a proof that clockwork was then in a very imperfect state. In 1577, Moestlin had a clock so constructed as to make just 2,528 beats in an hour, 146 of which were counted during the sun's passage over a meridian or azimuth line, and thereby determined his diameter to be 34′ 13″; so the science of astronomy began thus early to be promoted by clockwork; and astronomy, in its turn, gave rise to some of the most essential improvements in clockmaking. Martinelli, in his work printed at Venice, 1663, described an old clock going in his time in the Grand Piazza, in which two Moors struck the hour upon a bell, three kings entered from a door, and after making obeisance to figures of the Virgin and Child, placed in a niche, retired through a door on the opposite side. John Evelyn relates that about the middle of the seventeenth century, a man was killed by this famous clock: "While repairing the works, he stooped his head in such a position, and in such a nick of time, that the quarter boy struck it with his hammer, and knocked him over the battlements."

In the palace of Versailles are two curious clocks, one being the clock of the king's death, in the *Cour de Marbre*. This clock has no mechanism, and has only one hand, which is placed at the precise moment of the death of the last king of France, and is not moved during the whole of his successor's reign. This custom dates from the time of Louis XIII. In the saloon of Mercury is a clock dated 1706; each time that it strikes, two cocks flap their wings, small doors open, and two figures advance, holding bucklers, on which Cupids strike the quarters; a figure of Louis XIV. steps forth, and from a cloud, Victory descends and places a crown on the king's head; the puppets all disappear, and the hour strikes. In the little town of Lambex, there is on the top of a tower a human figure who strikes the hour with a hammer; as it does so, a woman appears, makes him a low curtsey, and then walks once round him.

Invention was, for a time, limited to enriching clocks by the addition of moving figures, processions of saints, with the Virgin, representations of mysteries and pious subjects; while others were made by the more learned to represent the motions of the heavenly bodies. Of this class were the two "wooden horologists" of St. Dunstan's, Fleet Street, which struck the quarters upon a suspended bell, each moving his head at the same time. These figures of savages, life size, carved in wood, stood beneath a pediment, each having in his right hand a club, with which he struck the bell. There is a like contrivance to the above in Norwich Cathedral; and a general name for these figures was "Jacks of the Clockhouse."

PROJECTION.—IV.

PROJECTION ON THE INCLINED PLANE.

On referring to the projection of the cube (Fig. 17), it will be seen that it is there represented as if placed with its faces at 45° to the vertical plane, the line of the diagonal of the plan being parallel to the vertical plane. We must now consider the mode of projecting views of objects, at whatever angle they may be placed in relation to both planes.

Let it be required, then, to project the cube when its faces are at 30° and 60° to the vertical, and when it stands on a plane inclined at 26° to the horizontal plane. It may here be pointed out, that in projecting *views* it is necessary to raise the objects at one side, or to place them on inclined planes; for otherwise, as they are supposed to be exactly on the level of the eye, the elevation only (as in Fig. 17) would be seen, but when raised at one side the top becomes visible.

Place the plan (Fig. 35) at the required angles to the intersecting line. Draw the line A (Fig. 36) at 25° above the line. This line represents the edge (or side elevation) of the inclined plane on which the cube is supposed to stand.

Draw the line B (Fig. 35) at right angles to the intersecting line, and from a b c d draw lines at right angles to it, and cutting it in a' b' c' d'.

Now it will be evident that these would be the widths which would be presented to the view of the spectator when looking at the sides a c d from the point C in direction of the arrow, and therefore, if perpendiculars equal to the height of the cube be drawn on a' b' c' d', and their extremities joined by a line parallel to B, D will be the elevation of those sides.

Fig. 36.—Transfer the points a' b' c' d' to the inclined plane (A), and on them construct the elevation as at D. The perpendicular at b is to be a dotted line; for, although known to exist, it would not be seen from C unless the object were supposed to be transparent.

Now, by drawing perpendiculars from the points in the plan, and intersecting them by horizontals from the points correspondingly lettered in the elevation, the projection E (Fig. 37) will be obtained.

It is now necessary to obtain the upper projection of the object—that is, the view from F, looking in the direction of the arrow.

Now it must be remembered that the elevation on the inclined plane is the view obtained from C (Fig. 35). It is therefore necessary that as this elevation has been turned round, the widths of the plan should be turned round also. Take the line e f, which in the plan is at right angles to the vertical plane, and place it (indefinite in length) parallel to the intersecting line (Fig. 38). Draw a perpendicular from a, in the elevation (Fig. 36), to cut e f in a. This gives the plan of the one angle of the top of the cube. From b draw a perpendicular, cutting e f in g, and from g set off on this perpendicular the distance b g' in the plan (Fig. 35), viz., to b. From c (Fig. 36) draw a perpendicular, cutting e f in h; from h set off h' c of the plan—viz., to c. From d draw a perpendicular cutting e f in i. From i set off the length i d of the plan. Join a b c d, and this figure will be the plan of the upper surface of the cube. From each of these points draw lines parallel to I L, intersect these by perpendiculars from the corresponding points in the *bottom* of the elevation, and lines connecting these points will complete the projection of the cube when viewed from above.

SIDE OR END ELEVATIONS.

The last lesson will have shown us that other views besides *front* elevations are necessary. These are called side or end elevations. In objects which are uniform in character, such as the cube (Fig. 37), the elevation of each end may be the same; but in a locomotive engine, a lathe, etc., the end elevations differ materially from each other, and in such cases several

drawings are necessary in their construction and in their projection.

The model shown in Fig. 39 is similar to that given in the first lesson; but the vertical plane, instead of being made of one piece, rotates on hinges at a b, and may be brought forward to c, so as to be at right angles to both planes.

Let us now place a thin metal plate, d e f g, perpendicularly on the horizontal plane, with its surface parallel to the vertical plane; then it will be seen that h i j k is the front elevation, and that the view when looking at its edge, in the direction of the arrow, will be the line l m projected in the plane a b c n, and this is the end elevation. If now this plane be turned back to its original position (that is, rotated on the line a b) until it forms a continuation of the vertical plane, and c has moved to c', the end and front elevation will appear on the

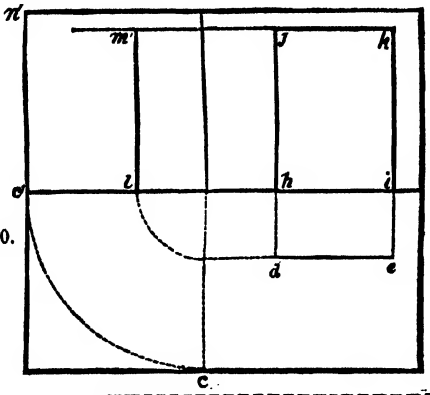


Fig. 40.

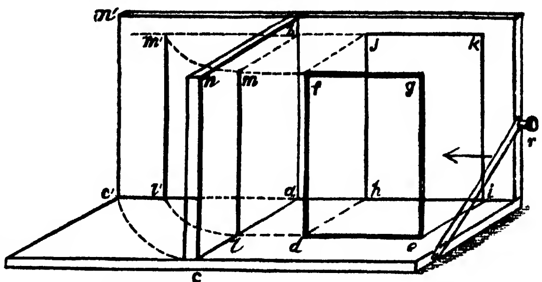


Fig. 39.

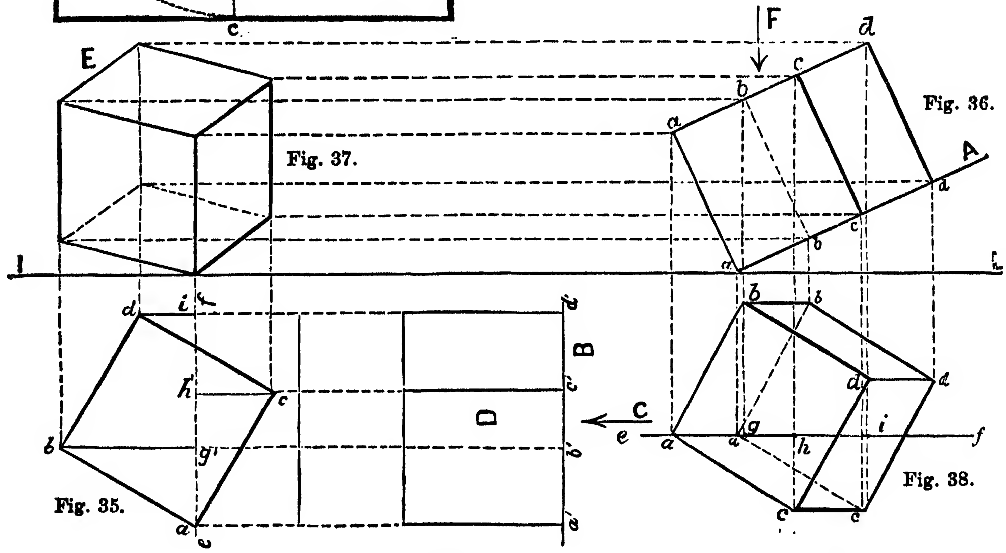


Fig. 37.

Fig. 36.

Fig. 35.

Fig. 38.

same plane; it will then be seen that the height of l' m' is the same as h j, and that in its motion the point l will have travelled through a quarter of a circle.

If now the vertical and horizontal plane be converted into one flat surface, by withdrawing the pin r, the plan and the front and end elevation will be found to be those represented in Fig. 40.

Fig. 41 is the end elevation, and Fig. 42 is the plan of a triangular prism when lying on one of its long sides, its edges being at right angles and its end parallel to the vertical plane; thus the exact shape of the end—that of an equilateral triangle—is presented to view. But when the prism is turned, so that the plan is at an angle to the vertical plane (Fig. 43a), the elevation (Fig. 43b) becomes materially altered; for as the object has rotated on the point b, a has receded, whilst f has advanced, and the apex, d, of the opposite end, which in Fig. 41 was hidden beyond c, now becomes visible; the height, however, remains the same as in the original figure.

Fig. 44.—Here the plan a b e f is further rotated until its edges are parallel to the vertical plane: the elevation is then shown in the dotted parallelogram, b c d e. Let us now raise the prism at one end (Fig. 45), so that its under side is at 20° to the horizontal plane. In this case it will be seen that the prism rests upon the line e f, and the points of the end elevation will now become visible in the plan, and if this plan be turned (as at Fig. 46) at an angle (say 45°) to I L, perpendicular lines from the points of the plan intersected by horizontal lines from the elevation will give the projection of the object at a compound angle (Fig. 47).

Fig. 48 shows the plan, and Fig. 49 the elevation of four such prisms meeting at a point, a figure which very frequently occurs in designing or drawing the roofs of houses, churches, etc.

The plan is formed of two figures similar to the plan of the last prism, crossing each other at right angles, and from this the elevation is easily projected.

Figs. 50 and 51 show the projections of the object when placed at an angle to the vertical plane; and Fig. 52 is the development of one of the four parts of which the model is composed. To construct this development on a straight line, set off three spaces equal in width to the sides of the prism, a' b f a, and erect perpendiculars from the points. Make these perpendiculars equal to the lines similarly lettered in the plan. Now it will be clear that when two parallelograms, like those forming the plan of the prism, cross each other, they will form four right angles at the centre. Therefore, at d' and e construct angles of 45°, which will meet in c and form the required right angle, and this will complete the under side. Draw c h and c i at right angles to e c and d' c, and equal to the altitude of the triangle a c in Fig. 41. Join d' i and h e. Then the right-angled triangles, d' c i and e c h, turned up at right angles to a b c d e, will form the upright sides of the mitre; i and h will then come together. The triangular end, which is repre-

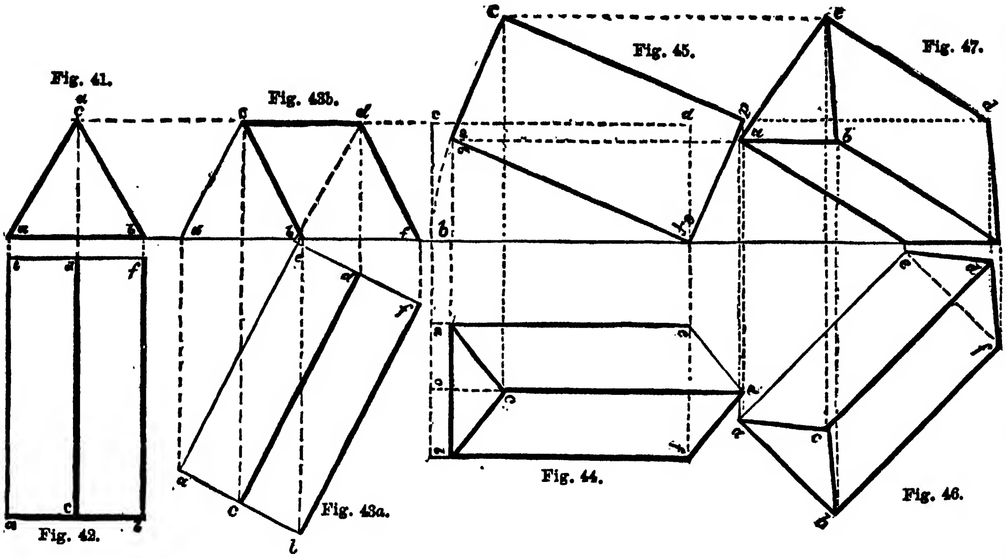


Fig. 41. Fig. 42. Fig. 43a. Fig. 43b. Fig. 44. Fig. 45. Fig. 46. Fig. 47.

sented as bent down, being now turned upward at right angles to the under side, the two upper sides are to be bent over. Then C will meet *h i*, *f* will meet *c''*, and *d a* will meet *d' a'*.

THE PROJECTION OF POLYGONS.

In Figs. 53 to 60 the mode of projecting a plane pentagon is shown.

Fig. 53. — Let A B C D E be the geometrical figure when lying flat on the horizontal plane with one edge, A and B, at right angles to the vertical plane; as in all the planes in a similar position, the elevation would be merely a line marking the greatest width, as A C E (Fig. 54).

Now let it be required to construct the plan of this figure, when the plane resting on A B is raised to an angle of 30° to the horizontal plane. Then, as each of the points C D and E will travel through portions of circles, draw a line at 30° at A on the intersecting line, and from A, with radius A C and A E, describe arcs cutting the line in points correspondingly lettered. This, then, will be the elevation. From *e* draw a perpendicular cutting E *f* in *e'*. From C and D draw lines parallel to E *f*. Then perpendiculars drawn from $^{d}_{c}$ in the elevation will cut these last-mentioned lines in *c' d'*. Join B *d'*, *d' e'*, *e' c'*, *c'* A, which will complete the plan of the figure.

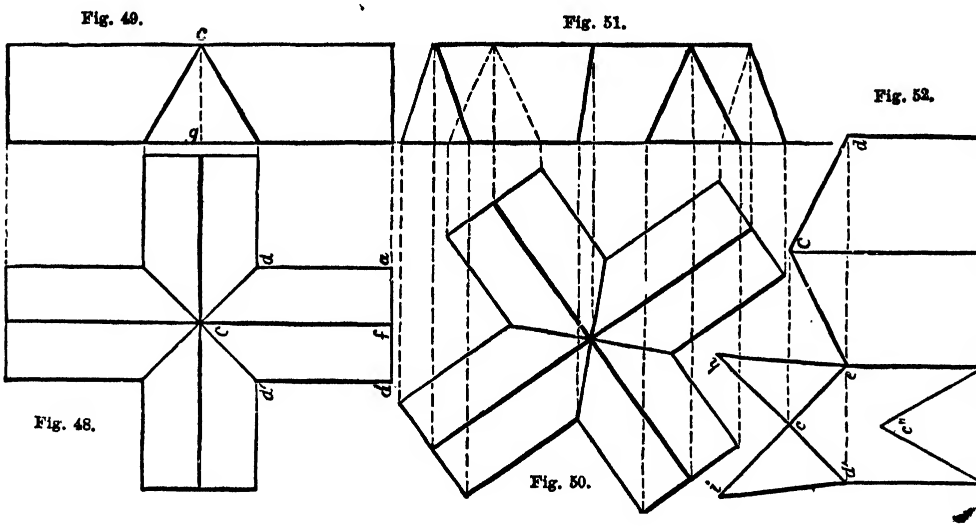


Fig. 48. Fig. 49. Fig. 50. Fig. 51. Fig. 52.

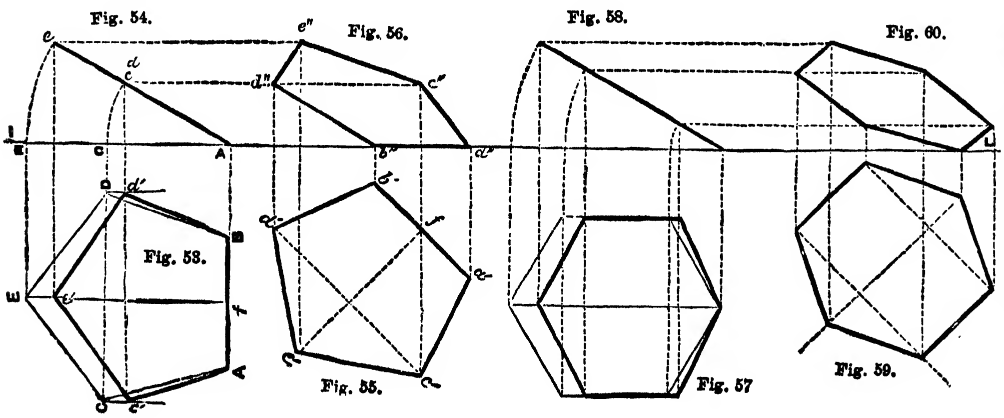


Fig. 53. Fig. 54. Fig. 55. Fig. 56. Fig. 57 Fig. 58. Fig. 59. Fig. 60.

Fig. 55.—Here the plan is turned, so that $a' b'$ is at 45° to the vertical plane, and it will be seen that by drawing perpendiculars from the angles of the plan, and intersecting these by horizontals drawn from the corresponding points in the elevation, the projection of the plane will be obtained. It must be remembered that the pentagon being "regular," * a line joining C and D will be parallel to A B, and will remain so, however much the plane may be raised. Thus, this line $c' d'$ is represented in the elevation by the point $\frac{d}{c}$—the line itself being *horizontal* and at right angles to the vertical plane (see Fig. 2, page 8). Now when the object is turned round this horizontal line becomes visible, and the perpendiculars from $c' d'$ intersecting it, give the points c'' and d'', and it will then be seen, that as the line joining these points was horizontal and parallel to A B in the previous figure, it will remain so in the projection; and this will explain the cause of *two* points in the plan coming on *one* line in the projection—a case which will frequently occur in the projection of polygons.

Figs. 57 to 60 show the same process adapted to a regular hexagon when resting on one of its angles, which it is expected the student will be able to work out without further instructions.

* A *regular* pentagon is one which has all its sides and angles equal.

ANIMAL COMMERCIAL PRODUCTS.—III.

DIGITIGRADA (*continued*).

THE *Skunk* (*Mephitis americana*) is common in North America, especially in the States of Pennsylvania and New Jersey. It is well known for its power of ejecting, when hunted, from a small bag placed at the root of the tail, a very offensive fluid, which produces one of the most powerful and intolerable stenches in nature. This animal is allied to the polecat of Europe. Its fur is soft and black, with two white stripes running from head to tail. The fur is purified by exposure to heat. The London imports of skunk furs amounted in 1886 to 488,385, which were mostly exported again to other parts of the world.

The *American Otter* (*Lutra canadensis*) is aquatic in its habits, and lives principally upon fish, which it pursues in the water. The colour of the fur changes with the seasons: in summer it is short and almost black, but on the approach of winter it alters to a beautiful reddish-brown. The motions of the otter in the water are very easy and graceful. The short, close, fine fur keeps the body at a proper temperature, and the short legs, webbed feet, and rudder-like tail enable it to move swiftly in any direction in pursuit of its agile prey. In 1886 nearly 20,000 otter-skins were imported into England from North America.

The Sea Otter (*Enhydra marina*).—The fur of the sea-otter is thick, soft, and woolly, and much prized in Russia and China, where it is the fur of royalty; to those countries most of the skins are exported. The animal is found in the North Pacific, from Kamtschatka to the Yellow Sea, on the Asiatic coast, and from Alaska to California on the American coast. It is a rare animal. In 1886 only 4,270 skins were imported into London from North America. The sea-otter haunts sea-washed rocks, lives mostly in the water, and approximates to the seal in its habits. Its fur is generally employed for collars, cuffs, and trimmings. It is very beautiful, of a deep velvety maroon brown, the anterior parts being of a silvery grey. A very fine skin of the sea-otter has fetched as much as £105, and a muff of this skin costs about twenty-five guineas.

2. PLANTIGRADA.

This group includes the family of the *Ursidæ*, or bears—heavy, stout-bodied animals, with thick limbs and a very stout tail—which inhabit the wooded and mountain districts of the Arctic, temperate, and sub-temperate regions of the northern hemisphere. The commonest bear-skin in the English fur-market is that of the

Black Bear (*Ursus americanus*), which is imported into this country generally from British North America, and chiefly for military accoutrements. It is made into caps, rugs, pistol-holsters, etc. In 1886 there were imported to the London market 18,773 skins.

The skins of the polar bear (*Thalassarctos maritimus*), the brown bear (*Ursus arctos*), and the grisly bear (*Ursus ferox*), are also imported by us in small quantities.

The *Racoon* (*Procyon lotor*) is indigenous to North America, and usually frequents the sea-shore and the margins of rivers and swamps, where it lives upon small animals, birds, insects, and mollusca, with the addition of roots and succulent vegetables.

In 1886 no fewer than 477,283 skins of the racoon were imported into the United Kingdom. Two-thirds of this number were re-exported, principally to Germany, where they are used for making hats. The hair of the upper part and sides of the body is of uniform length and colour, and is employed for the linings of coats, for rugs, etc.

The *Badger* (*Meles vulgaris*, Desmarest) is found throughout the northern parts of Europe, Asia, and America. Its habits are nocturnal, inoffensive, and slothful. Its feet are plantigrade, and its long claws enable it to dig with effect, and burrow in the woods. It feeds on roots, earth-nuts, fruits, insects, frogs, and the eggs of birds. Its muscular strength is great, and its bite proverbially powerful. The American badger (*M. labradoricus*) is larger than the European species. In 1886 as many as 6,402 skins were imported into London from North America. The long hairs are employed for making shaving brushes and painters' pencils. In Europe, badgers are hunted with dogs; in America, they are caught in early spring, whilst the ground is frozen, by pouring water into their holes.

The *Glutton*, or *Wolverine* (*Gulo luscus*) inhabits the northern parts of the American continent. Wolverines feed chiefly upon the carcases of beasts which have been killed by accident. They are very troublesome to the Hudson's Bay trappers, for they will follow the marten hunters' path round a line of traps extending from forty to sixty miles, and render the whole unserviceable, by removing the baits, which are generally the heads of partridges or bits of dried venison. They resemble the bear in their gait, and feed well; they are generally, when caught, found to be very fat. The fur is a fine deep chestnut colour, with a dark disc on the back. It is much esteemed in Germany and Russia, and manufactured into cloak linings, muffs, and sleigh robes. In 1886 the London import of wolverine skins amounted to 1,631.

3. PINNIGRADA.

This group includes the family *Phocidæ* (Latin *phoca*, a seal), and comprises the seals, sea-bears, and walruses, which are found chiefly in the arctic and antarctic seas, and are of great value alike for their oil, bones, and skins. The chief hunting-grounds are the fields of pack ice in the Greenland seas, and around the shores of Spitzbergen.

The Saddleback or Harp Seal (*Calocephalus grœnlandicus*).—This species, which is the most important of the *Phocidæ* in commerce, is at all times gregarious, but never seen to assemble in such numbers as during the months of March and April, when it takes to the ice to bring forth its young. During those months a pack of ice three miles in diameter has been calculated to have no fewer than four millions of seals upon it. Its length does not exceed eight feet. The name *saddle-back* is given to it from an aggregation of black well-defined spots scattered over a yellowish-white ground in the form of a saddle or harp.

For the capture of this seal, especially during the breeding season, many ships are annually sent out, and the number taken yearly amounts to hundreds of thousands. The success of the sealers varies; for a ship one year may obtain as many as 20,000 seals, and next year not capture a hundred. The chief art of sealing lies in finding out where the main body of seals is located; a sort of instinct directs these animals in flocks of hundreds to a common centre, where they remain in one great group till the young are capable of taking to the water.

This species is highly prized. From its blubber the Greenlander and Esquimaux procure light and heat; they cover their boats and bodies with its skin, make thongs with its entrails, a *derg* or float with its stomach, and ingeniously fashion the teeth into tips for their arrows and harpoons.

The *Bladder-nose Seal* (*Stemmatopus cristatus*) inhabits, as the last, the Greenland seas, and is found in small groups of

three or four. On account of the beauty of its fur, and the immense amount of its blubber, it is much sought after. It differs from the other species in having a thick black—in the young, delicate brown—woolly coat, which lies beneath its outside bristly hair.

The *Common Seal* (*Phoca vitulina*, L.) is found on the coasts of Scotland, France, and other parts of Europe. The usual haunt of this species is a hollow or cavern in a rock near the sea, and above high-water mark. They are extremely watchful, seldom sleep more than a minute, raise their heads, and, if nothing is to be seen or heard, lie down again; but if disturbed, they instantly tumble off the rocks into the sea. They are usually shot when asleep. If surprised by the hunter at a distance from the shore, they hasten to the water, flinging stones and dirt behind as they scramble along, and expressing their fears by piteous moans. When overtaken, they make a vigorous defence with their feet and teeth until killed.*

RODENTIA.

The *Rodentia* (Latin, *rodo*, I gnaw), or gnawing mammalia, are, for the most part, of small size, but numerous and prolific. They are distributed all over the world, even in Australia, which possesses some few indigenous species. They have two pairs of curved cutting or incisor teeth, which project from the front of each jaw, and from two to six molars on each side, but they are devoid of canine teeth. The rodents of the greatest value in the fur market are—

The Beaver (*Castor fiber*, L.).—This animal is found in Canada, where it frequents the banks of rivers and marshes, making large dams with the stems of trees plastered with mud to keep out the water, and building rude dwellings in the water, with considerable engineering skill and ingenuity. The fur of the beaver consists of two kinds of hair, one long and rigid, forming the outer coat, the other soft and downy; it is the latter which is employed for coat linings, muffs, and other articles of dress, though the demand for them has fallen with the introduction of silk to the hat industry. In 1886 the London import reached 117,161 skins.

The Musk Rat, or Musquash (*Fiber zibethicus*).—This animal is a native of Canada. It is much smaller than the beaver, which it resembles in its fur and habits, and with which it associates. The importation of musquash skins into London in 1886 amounted to the enormous quantity of 2,393,017 skins. Dressed in the same way as beaver-skin, they form a cheap and durable fur for ladies' wear.

The *Nutria*, or *Coypu Rat* (*Myopotamus coypus*), inhabits South America, living near streams, and burrowing in their banks. It is smaller than the beaver, and also differs in the possession of a round, hairy tail. Its skin forms a good substitute for that of the beaver, and is dressed in a similar manner. In some years one million nutria skins have been imported from South America into the United Kingdom.

The Squirrel (*Sciurus vulgaris*, L.).—Light, nimble, and graceful animals, living on the branches of trees, feeding on nuts and other hard fruits, which they gnaw through with their sharp front teeth, carefully removing every particle of the skin from the kernel before eating it. Squirrels are distributed through all parts of the world except Australia, but are especially abundant in North America. Their skins are used entirely for ladies' and children's wear, and are sent in enormous numbers to our fur markets under the name of *calabar*. We import great quantities, and devote them to various purposes. The fur is sometimes dyed to imitate sable. The tail is used in the manufacture of boas and artists' pencils. Besides the common squirrel, *Sciurus cinereus* (the grey squirrel), *S. niger* (the black), *S. caroliniensis*, and *S. hudsonius* (the American red squirrel) yield useful and ornamental furs.

The Chinchilla (*Chinchilla lanigera*).—An elegant, active little animal, inhabiting the Andes of South America, in Chili and Peru, and living at a considerable altitude. The posterior legs are longer than the anterior, and the animal when feeding sits upon its haunches, holding its food between its short fore-paws. The ears are very large and broad. The fur, which is very thick, soft, and of a greyish colour, reaches us through the South American markets. Chinchilla fur is greatly admired for winter clothing, and is made into muffs, mantles, boas, cloak linings, trimmings, and other articles for ladies' and children's wear.

The Hare (*Lepus timidus*) *and Rabbit* (*Lepus cuniculus*).—The skin of the rabbit, when dressed and dyed, is made into all sorts of cheap and warm winter clothing; that of the hare is frequently worn over the chest as a protection against external cold. We have large supplies of rabbit-skins sent to our markets from the rabbit warrens of Norfolk, the Orkney and Shetland Islands, and Ostend. Upwards of 1,000,000 rabbits are sold yearly in London, and more than a quarter of a million of hare-skins are annually imported into this country from Russia, Germany, Denmark, Friesland, Poland, Wallachia, Turkey, Greece, and Sicily. The best and the greatest number come from Russia.

RUMINANTIA.

The animals of this order are distinguished from the other mammalia by the remarkable facilities which they possess for ruminating, or chewing their food twice over. In the majority the lower jaw alone is furnished with incisor teeth, their place in the upper jaw being occupied by the hardened gum. The molars are separated from the incisors by a considerable gap in the jaw. Examples: sheep and deer.

The American Buffalo, or Bison (*Bison americanus*, L.).—Vast herds of buffaloes roam over the western prairies of North America, and hundreds of thousands of them are annually killed. Buffalo robes are much esteemed in America as sleigh coverings; about 70,000 are annually made up and sold in New York. During the Crimean war our soldiers found these robes of great service; about 20,000 buffalo robes were furnished by the English Government amongst other army supplies.

CHEMISTRY APPLIED TO THE ARTS.—II.

BY GEORGE GLADSTONE, F.C.S.

DYEING.

THE art of dyeing was discovered at a very early period of human history, and is practised by nearly all races of men; nevertheless, it has greatly profited by the advance of science, and even within the present generation it has been the subject of very great improvements. Many of the colours now regarded with most favour were altogether unknown to our fathers, while others have been rendered more permanent, and most have been cheapened in cost.

The materials used in dyeing are derived from very various sources, and their number is legion. There is, indeed, scarcely any limit to the variety that might be employed, and in an article like the present we can pretend to name only a few of those which are most commonly used by dyers. They form two distinct classes, which must be constantly borne in mind, in order to arrive at a clear comprehension of the dyeing process:—(1) The colouring matters; (2) The mordants and alterants.

1. The great majority of the colouring matters in use are derived from the vegetable kingdom, though some of the others are of the very greatest importance. Of these it may suffice to name alkanet root, aloes, annatto, orchella and other lichens, barberry root, barwood, Brazil wood, camwood, logwood, Saunders' wood, yellow berries, indigo, madder root, quercitron, safflower, turmeric, woad, and weld. The animal kingdom supplies the cochineal and kermes, which, as well as lac, an exudation produced by an insect, furnish very beautiful varieties of red. The metals arsenic, chromium, copper, iron, etc. in the form of salts, all produce valuable colours, though the compounds of arsenic are very deleterious both to the dyer and to the wearer of clothes so dyed, and should certainly be discouraged. There are also some artificial products which have been successfully prepared by modern chemists, and which bid fair to greatly alter or even revolutionise the art of dyeing; thus, what are called the aniline compounds have furnished some of the most favourite dyes; and alizarine, a still more recent

* For further details about furs and skins, and for information generally upon technical and industrial products and processes, the reader should consult the Society of Arts' admirable volume, excellently edited by Mr. H. Trueman Wood, M.A., of "Reports" on the Colonial Section of the Colonial and Indian Exhibition which was held in London in 1886.

production, will probably soon dispense to a great extent with the use of madder roots, the bulkiness of which considerably enhances the cost of bringing them from abroad.

2. The most important mordants and alterants are the alums, the salts of iron and tin, and a variety of vegetable substances which contain tannin. Of these last the principal are catechu, fustic, sumach, gall-nuts, dividivi, valonia, myrobalans, etc. Some of them exercise a double function, and might be included amongst the list of colouring matters, but their chief value brings them more appropriately under the second category.

The operation of the first class needs little explanation, but that of the latter lies at the very root of the art. It will readily be understood that a highly coloured liquid may be obtained by boiling down or steeping certain substances in water, and that if a piece of calico be immersed in the solution, it will take up a certain amount of the colour; but it follows almost as a necessary consequence that a dye so produced can be washed out again with almost equal readiness. If this were all, dyeing would be of no value. The importance of mordants consists in their so fixing the colours that they shall not wash out or otherwise lose their depth or brilliance; and that of alterants in their bringing out or changing the tint produced by the dye stuff. By means of the latter a much greater variety of shades is obtained, and even some colours which can scarcely be derived at all from a mere combination of dyes.

Some very interesting chemical reactions take place in the use of the dyes mentioned under the first head, which must be noted, as they are highly instructive. By far the most important in the list of vegetable substances is indigo. It is commonly known in this country as a lump of purplish stuff, having a bloom upon it like a ripe plum. In the dye vat, however, it presents a very different appearance. Indigo, in the state in which it is imported, is actually insoluble in water, and most other solvents will not even touch it; but by expelling the oxygen which it has absorbed in the course of preparation, it returns to its original condition of white indigo, which is soluble in an alkaline liquid. The blue indigo of commerce is therefore ground up with water till it forms a thin paste, then put into a vat of water and stirred up with sulphate of iron (copperas) and lime, in the proportion of 1 lb. of indigo to 2 lb. of sulphate of iron and 3 lb. of lime; the result is that the sulphuric acid leaves the iron and combines with an equal quantity of the lime, the oxygen of the blue indigo takes the place of the sulphuric acid which has left the iron, forming an oxide of iron, and the excess of lime which remains in the water renders the indigo soluble. The indigo having parted with its oxygen is no longer blue, but has returned to its original colourless condition. When the sulphate of lime and oxide of iron which have been produced in the vat have thoroughly settled to the bottom, the cotton fabric or yarn which has to be dyed is dipped into the liquor, and the fibres become filled with the solution. The goods are then taken out of the vat, hung up, and exposed to the action of the air, when the oxygen out of the atmosphere again enters into combination with the white indigo in the fibre of the cloth, and restores its blue colour. This blue indigo being, as already mentioned, altogether insoluble in water, we have here a permanent colour which cannot be washed out. Wool may be dyed by precisely the same process, except that the liquor in the vat must be maintained at a high temperature, whereas cotton is dyed cold. Other modes of using indigo are employed by some dyers, or for special purposes, in which madder is a principal ingredient, but in every case the result is due to the chemical action above described.

Indigo naturally leads to the consideration of what are commonly known as the aniline dyes, so named from their chemical relation to this substance, *anil* being the name given by the Spaniards to indigo. The terms *mauve*, *magenta*, etc., are now familiar as household words, though less than half a century ago the colours represented by them were quite new to the public. Aniline itself, which was originally made from indigo, had been produced from coal-tar by two or three different processes; until the date above referred to, however, the substance had not attracted any very special attention, and its compounds were not known to produce the colours now so familiar. This discovery was due to Mr. Perkin, and the demand which suddenly sprang up for the dye soon led to the manufacture of aniline from coal-tar, on a scale never before attempted, and, by subsequent improvements in the process, at a much more moderate price than heretofore. The mode of application of these dyes will have to be considered later on.

Madder is perhaps next in importance to indigo, and possesses some special features of interest, though the processes involved in its use are by no means so simple as those above described. This dye has hitherto been obtained from the roots of the *rubia tinctorum*, a plant which is largely cultivated in the south of Europe and in Asia Minor. Its value consists in its containing a substance called garancine or alizarine. This article will furnish, in combination with various other ingredients, a variety of tints, from yellow to orange, and up to a deep red. Unlike indigo, it requires the presence of a mordant in order to secure a satisfactory result. The one generally used in dyeing with madder is alum. The cloth to be dyed is first steeped in a solution of alum, and being thoroughly impregnated with this article, it is ready for the reception of the dye which may be intended. Let us suppose that an intense red is required; a solution of alizarine with one of the alkalis (such as ammonia or soda) would be used, and into this the cloth, already permeated with the alum, would be introduced. The mordant would take up the alizarine until it was thoroughly saturated with it, the cloth thus acquiring the desired colour; but were the process to be continued beyond this point, the excess of alizarine in the liquor would be liable to further decomposition, producing a new compound, called rubiacin, which would have the effect of rendering the colour more dull; it is therefore important so to regulate the relative proportions that this after effect may not take place. The madder roots themselves contain but a small per-centage of the colouring matter, the inevitable result of which is that the dye is costly. So important an article is it, however, that, notwithstanding the price, it is very largely used both in this country and on the Continent. Chemists, in consequence of this, were led to study the composition of this dye, and their labours were at length rewarded by the discovery of a means of producing artificial alizarine which fulfilled all the reactions of the natural product. The history of this achievement is one of the deepest interest to the experimental philosopher, as well as to those who are likely to profit by it in a commercial point of view. It would take up too much space to describe all the steps by which the result was finally attained; suffice it to say that from a study of the chemical formula (consisting of definite proportions of carbon, hydrogen, and oxygen) $C_{14}H_8O_4$, it was believed to bear a certain relation to other substances which are produced artificially. This view was confirmed by converting some of the alizarine taken from the madder roots into anthracene ($C_{14}H_{10}$), which is obtained by the distillation of coal tar. This having been proved, it only needed a means of reversing the operation, which was afterwards discovered—alizarine, absolutely identical in all its properties with the dye obtained from the madder roots, having been made from anthracene. A second source of supply of an article quite indispensable to the dyer is thus provided by the mineral kingdom.

Chromium, in the form of bichromate of potash, is a metal which is very extensively used, especially in the formation of yellows, orange, and reds. In dyeing cottons the process depends upon a chemical reaction, the fabric being first immersed in a solution of one of the salts of lead, so as to supply a base which possesses a greater affinity for the chromium than potash does. Thus, if the goods be impregnated with nitrate of lead, and subsequently with bichromate of potash, the chromium will leave the potash and combine with the lead, forming chromate of lead, which produces a yellow dye. Again, should an orange colour be required, the process can be carried a step further; the article so dyed yellow would then be boiled in a bath of lime-water, during which operation the lime will take up a portion of the chromium, leaving a subchromate of lead behind, which produces a rich orange. Some persons use acetate of lead in preference to the nitrate, but the principle involved in either case is the same. Chrome is also employed in dyeing woollen goods with various colours, in combination with many of the vegetable dyes; in these operations alum is almost always used as a mordant, and the solution into which the

article to be dyed is dipped must be maintained at the boiling-point.

The use of a mordant has incidentally been mentioned in treating of madder and the chromates of potash. Its proper function is to fix the dye, so that it shall not wash out again. Alum, as we have seen, has this property; a fabric which has previously been dipped into a solution of alum being able, not only to take up a much larger quantity of some colouring matters than it would otherwise, but also to retain them so persistently that the colour becomes fast. In some cases the mordant and the dye are applied separately, while in others the two are mixed, forming a coloured liquor in which the article to be dyed is steeped, and so far reducing the number of operations. It appears probable that the action of such a mordant as alum is to enter into actual combination with the substance of the thread or cloth, and not merely to fill the capillary tubes with a substance insoluble in water, as in the case of cotton dyed with indigo; hence, in consequence of the greater affinity of alum for animal substances than for other materials, the effect of this mordant is much more decided when applied to wool and silk than to cotton and flax.

Various salts of iron exercise, in a pre-eminent degree, the double function of mordant and alterant. Sulphate of iron, or copperas, is, for instance, used as such in dyeing cotton blue with ferrocyanide of potassium or the red prussiate of potash, while the nitrate or sesquichloride of iron, combined with the ferrocyanide or yellow prussiate of potash, will produce the same result; the chemical action in either case is the same—the acid leaves the iron and combines with the potash, while the cyanogen completes the exchange by uniting with the iron, thus forming a compound cyanide of iron, commonly known as prussian blue. Here we have an illustration of the effect of an alterant, the resulting colour having no relation to that of the ingredients which are brought into combination, but being due to chemical action only.

Of all the metals, however, tin is the most important as a mordant, the various oxides of tin having a very powerful affinity both for vegetable colouring matters and for the materials which are to be dyed. The effect of these salts (or spirits, as they are called by the dyers) is to produce very permanent colours. The salts generally used in the dye-house are the chlorides; the oxides being insoluble except in the presence of an acid, or in combination with an alkali, such as soda, in which case the tin itself acts the part of an acid, forming stannate of soda.

A great variety of vegetable substances, all containing tannin in more or less quantity, are used in dyeing, which act both as mordants and alterants. The tannic and gallic acids which they furnish exercise a very powerful chemical action upon some of the other materials employed, especially the metallic salts. With sulphate of iron these acids produce a deep black, of which the common writing-ink furnishes a familiar example.

To give a description in detail of all the various processes for dyeing different kinds of goods, and of the several combinations which are best adapted to produce the almost endless varieties of tint, would fill a goodly volume. In the next article some of the most important general directions will be given, and one or two of the principal colours will be treated at length, as an illustration of the nature of the dyer's art.

AGRICULTURAL DRAINAGE AND IRRIGATION.—II.

By J. Wrightson, Professor of Agriculture, Royal School of Mines.

WATER-LOGGED SOIL—ADVANTAGES OF LAND DRAINAGE.

The beneficial action of land drainage may at first sight appear somewhat paradoxical. That the partial removal of water, the want of which is often so keenly felt, which may be beneficially poured over growing crops in quantities far exceeding the natural rainfall, and which not unfrequently composes ninety per cent. of the actual weight of fresh vegetables—that the removal of this most essential constituent of plants from the soil should be attended with good effects certainly appears puzzling, and demands our careful attention. It will, then, be our first object to explain why the drainage of land is beneficial; and, secondly, we shall point out the nature of those practical good effects which have rendered the art popular.

Let us consider the condition of a soil surcharged with moisture, and compare it with one in which, from natural or artificial means, the superfluous water finds egress.

The fact that the land is wet is sufficient proof that some obstacle exists preventing the escape of water. The subsoil may be sufficiently impervious to prevent the downward passage of water to lower strata, or there may be a source of water in the form of springs too plentiful to allow of its sufficiently rapid removal by natural drainage. From either or both of these reasons the land is "water-logged," by which we mean that all the interstices of the soil that would otherwise be filled with air are occupied by water. This water is in a stationary condition. If it is not, it will move in the line of least resistance, and the soil will be more or less perfectly drained. Having, however, assumed that the soil is wet, we must conclude that its condition is the effect of the water not being able to escape.

(1.) What, then, are the consequences of this stagnant condition? In the first place, air is excluded. Now the effect of air upon the soil is most beneficial, and without it it is impossible for any plant to develop. The first consequence of an insufficient supply of oxygen is the formation in the soil of organic and inorganic substances of a decidedly deleterious character. Vegetable matters remain in a state of partial or imperfect decomposition. Such a condition is unfavourable to plant life; and its evils are the more apparent when we remember that with a sufficient supply of oxygen such compounds would not only be removed from an actively hurtful state, but would become a source of carbonic acid and ammonia (the products of perfect combustion), and thus directly nourish growing crops. Lower oxides and sulphides of iron are also the result of decaying vegetable matter in the soil, which, in its condition of arrested decay, removes the oxygen previously associated with iron, thereby reducing the peroxide to the condition of protoxide. The removal of superfluous water at once admits air, and with it oxygen, and by this means the soil is brought into a "sweeter" and more wholesome condition.

(2.) Water, when it exists in a stationary or stagnant condition in a soil, fails to exert those beneficial influences that constitute its peculiar value. Rain-water contains traces of carbonic acid, as well as of other valuable substances. This carbonic acid exerts a solvent action upon the mineral matter in the soil, gradually changing it from an insoluble and unavailable condition into one in which it can be assimilated by the roots of plants. It is only, therefore, in drained or naturally dry soils that the valuable qualities of rain can be thoroughly realised.

(3.) Not only is rain comparatively valueless to wet soils, but there is a danger of its becoming actively injurious. Not being able to sink into the already occupied soil, it washes the surface, and, as it trickles into the water-furrows and ditches, carries with it the finest particles of earth, as well as manurial substances that have been applied as fertilisers. This is, however, not the worst evil consequent upon defective drainage. The top layer of soil becomes surcharged with moisture, and this can only be got rid of by evaporation. The larger the surface, and the more completely it is exposed to the air, the greater will be the evaporation. In the case of drained soils, the water is quickly removed from the effect of drying winds, and evaporation is proportionally checked. In wet soils, on the contrary, the conversion of water into vapour is the cause of a greatly diminished temperature.

It has been calculated that the heat given off from the combustion of 1 lb. of charcoal is required to evaporate $12\frac{1}{2}$ lb. of water, and when we remember that the rainfall upon an acre of land is equal to something like 6,000,000 lb., it will be readily seen that, where a large proportion of this is to be evaporated, much of the sun's heat, which would otherwise be warming the ground, will be taken up.

(4.) Another reason for the wonderful improvement of land by drainage is the altered texture of the soil. So long as land is constantly wet, its condition, although unfavourable to plant life, is in some respects constant. It is not subjected to the modifying influences of contraction and expansion to so great an extent as drained soils. A drained field is alternately, and

within very short periods, dry and wet; it is also acted upon by the atmosphere, and that weathering action which, in the long course of time, has broken down and pulverised rocks, and so formed soils, is promoted, so that further pulverisation and a finer mechanical condition of the soil is the result. The alternate contraction and expansion also causes the formation of a deeper layer of available soil, and renders lighter the work of cultivation. As water rises from the deeper layers of the soil to the surface, it brings with it the saline substances it has taken up in solution. These are carried by capillary action to the surface, where, as the water is evaporated, they are left in the form of an incrustation, which to a great extent prevents the entrance of air into the soil. This phenomenon is frequently noticed in the case of flower-pots watered by means of a saucer. In this case the water, as it evaporates from the upper surface of the soil, leaves a white efflorescence which, from the cause already referred to, is prejudicial to the plant, and requires to be frequently broken up in order to admit air. The same phenomenon has been observed in the case of agricultural soils.

Having traced the causes of the beneficial action of land drainage, we may now glance at those many practical advantages which appeal to the common sense of the landowner, the farmer, and the public. That drained land grows a better crop than undrained land is easily accounted for when we remember the improved chemical and mechanical state of the soil. As every reason we have given points in the direction of an improved condition of soil, it need not surprise us that one quarter of wheat to the acre has often been estimated as the average increase that may be expected after drainage. Instances are not wanting where land has been brought from a worthless into a valuable condition simply by draining it, but the above given measure of the benefit is applicable to soils which, although requiring drainage, were previously useful agricultural soils.

An earlier harvest is a palpable advantage from drainage, and can be explained by the general improvement of the land, and the higher temperature of the soil consequent upon diminished evaporation. Mr. Parkes, the eminent drainage engineer, found, from the mean of thirty-five observations, that a drained peaty soil at seven inches in depth was 10° Fahrenheit warmer than a similar undrained soil at the same depth. This, it will be seen on inspection of any table of temperatures throughout the year, is equivalent to the difference between the climates of February and May. The result of this improvement is harvest a fortnight earlier, and an improved quality as well as quantity of produce. The same causes operate in increasing the number of species of plants which the farmer can cultivate. Thus we find the *bare fallow* disappearing, and root and forage crops occupying the ground. Sheep stock also can be maintained, whereas previously they could not have been profitably kept. Every tillage operation is more easily and effectively performed, and, owing to the water being quickly carried away, the actual number of working days is increased. Thus either a smaller number of horses will be required, or those that are kept will be more equally worked and less expensively fed.

Manures are much more effective upon drained soils; hence this operation is now looked upon as the foundation of good husbandry, and the best farmers consider that it should precede every other improvement.

Grass land derives great benefit from drainage. It sooner assumes a beautiful green colour in the spring; it is firmer under the foot; rushes, sedges, and other water-loving and inferior herbage disappear, and are replaced by nutritious grasses.

The health of the live stock is unquestionably improved, and land drainage is followed by the disappearance of "black-quarter," or inflammatory fever, which in unfavourable situations is a cause of annual loss. The health of the human population is also improved.

Before leaving this most interesting part of the subject, we would recall the attention of our readers to the fact that drainage owes its efficacy to the alteration in the condition of the water in the soil rather than to its withdrawal. If we remove water, it is only because it has accomplished its work, and we facilitate its exit to make room for a new supply. Thus the drainer's art consists, as has been well remarked, not only in getting the water out of the land, but also in getting water *into* the land, and thoroughly using its valuable properties.

We propose, upon a future occasion, after considering the cost of drainage, to select a few instances showing the extent to which land has been improved by the operation; but at present we must pass on to another important point in the theory of drainage—namely, the action of drains in removing water from the land.

THE WATER ECONOMY OF SOILS.

Soils are wet from three causes:—(1) The direct fall of rain; (2) springs; and (3) moisture which finds its way from higher porous strata on to lower ground in a diffused condition.

How far these three sources of wetness are the cause of injury in any given case depends upon the structure of the soil and subsoil. Clay soils, with retentive subsoils, are liable to be wet from the first cause, and they may receive an additional supply from the percolation of water from higher grounds. In soils of a light character resting upon a tenacious clay (a combination not unfrequently met with), the natural rainfall may also be the direct cause of wetness. Springs are met with when a porous soil is underlaid by a clay bed. The rain sinks at once through the upper stratum until it is arrested by the impervious bed beneath. There it accumulates and rises until it either wets the surface or, following the line of least resistance, bursts out at a lower level in the form of a spring. Springs are very commonly seen upon the sides of hills.

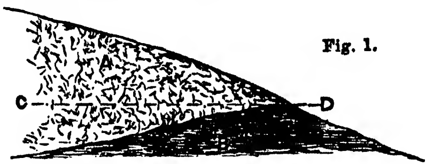


Fig. 1.

The accompanying diagram (Fig. 1) shows the conditions under which springs often occur. A represents a porous stratum; B represents a clay bed which obstructs the downward passage of water; C D represents the level to which water will require to rise before it overflows in the form of a spring at D. In dry weather, when the "reservoir" or "water-table" sinks below the line C D, the spring will be dry; but on the return of wet weather it will again become active. These facts exert an important influence upon the practice of drainage.

The drainage of *porous* soils is exceedingly simple. All they require is an outfall for their superabundant water. They are wet simply because the water they receive direct from the clouds, or from higher levels, cannot escape; and when egress is given to this superfluous moisture, they at once take their place among naturally dry or drained soils. With clay soils the case is somewhat different. Not only must an outfall be given, but the whole bulk of the soil between the drains must be thoroughly aërated before their drainage is complete. Such soils hold the water which incommodes them with a tight grasp, and a much more close and complete system of underground channels, supplemented by steam or other deep cultivation, is necessary before the same effect is produced as in the case of lighter soils. Thus, in light, porous soils the distance between the drains is sometimes as great as sixty yards, while in clay soils they are often placed only six yards apart.

In order to understand the action of drains, it is necessary to bear in mind that in all wet soils there exists, at a greater or less distance from the surface, a something which prevents the escape of water; that the effect of continued rain, or an accession of water from other causes, tends to accumulate water upon this obstruction, thereby forming a "water-table" or level of supersaturation; and lastly, that above this supercharged level the soil is wet by capillary attraction, which lifts the water to a greater or less height according to its texture and condition. Before land can be thoroughly drained it is essential, not only to lower the "water-table," but to so lower it that capillarity shall not so saturate the superimposed stratum as to render it injurious to growing vegetables.

In our next paper we hope to still further elucidate this portion of our subject, and to point out the important action of capillary attraction in the water economy of soils.

BUILDING CONSTRUCTION.—III.

FOUNDATIONS UNDER WATER.

In our previous lessons on this subject we have insisted on the necessity that exists for procuring a good foundation for buildings of all kinds, and have explained the methods of effecting this by the employment of concrete and piles in soft soil of any description. We now pass to the mode of making foundations under water.

Foundations under water are constructed in various ways. The most ancient, and certainly the most simple, is that called by the French "pierre perdue" (or lost stones). This method consists in shooting rough stones, etc., into the water, and leaving them to settle themselves as they happen to fall. When the heap rises to the surface, it is levelled, and the superstructure raised upon it. This system has been used principally for the erection of piers and breakwaters, but is not adapted for structures of a permanent character, as lighthouses, being erected upon it, as the external portions are liable to be washed away, and therefore the mound requires frequent repair. Nor do the stones always fall exactly within the prescribed area, but may reach a greater distance than was intended. The system is, therefore, not adapted for river works, where any narrowing of the water-way for vessels is of consequence.

A breakwater is a barrier intended for the protection of shipping in harbours or anchorages, by *breaking* the force of the *waters* as the mighty waves roll towards the shore. Sometimes a small island is situated opposite a bay, and thus forms a *natural* breakwater. This is in some degree the case with the Isle of Wight, which occupies such a position as to protect Portsmouth and Southampton.

The Plymouth breakwater (Fig. 1), built by John Rennie,* is the best known of these constructions. The Sound, or harbour, being open to the south, was so much exposed to storms, that early in the present century it was determined to erect a breakwater across it, with openings on each side between it and the shore to allow of the passage of vessels. The works were commenced in 1812, by transporting along a tramroad large blocks of limestone from a neighbouring quarry. These were then carried by vessels fitted with trap-doors, and were thus deposited on the required spot. The good effect of the mound was felt as soon as it began to rise above the surface, but the great storm in November, 1824, threw a large quantity of the stones over into the Sound, and it was not until 1841 that the works were finally completed by the deposition of more than 3,000,000 tons of stone, and the expenditure of £1,300,000. The breakwater is nearly a mile long. The central portion is 1,000 yards, and two wings, of 330 yards each, extend from the ends of this at a slight angle. The open channels at each end, between the breakwater and the shore, are each about half a mile wide, and their depth is respectively 40 feet and 22 feet at low water. The breakwater is 133 yards wide at the base, and 15 yards at the top, the two sides being made very sloping for the security of the stones; the slopes and top are faced with masonry. The water-space or area forming Plymouth Sound, which is protected by this breakwater, comprises 1,120 acres.

There are breakwaters at Holyhead, Portland, and Dover, but the limits of the present lessons preclude descriptions of them. The above description of the Plymouth breakwater will therefore serve as an illustration of the system of "pierre perdue" or "random" foundation. In some cases blocks of *béton* have been used with success.

Foundations under water are sometimes laid in *coffer-dams*. This is done by driving parallel rows of piling around the site on which the pier is to be built; these piles are kept in their places by horizontal timbers, so as to form a coffer or strong box around the site. The space between the parallel rows of piling is filled with clay, puddle, etc., well rammed down, so as to render the wall thus formed water-tight; this is one of the principal difficulties in the system, whilst another presents itself in the pressure of the water on the outside, which is resisted by struts placed inside the coffer-dam, extending from side to side. When the coffer-dam takes the form of a wall, and is intended to keep out the water during the building of a wharf, quay, etc., the struts are placed obliquely, and act as buttresses.

When the structure is deemed satisfactory, the water is pumped out of the enclosed space, the bottom of which is then excavated and levelled until a solid stratum is reached, or, if there be any difficulty in doing this, a bed of concrete or *béton* is laid down.

If solid ground is not found within available depth, the plan adopted is to drive piles a few feet apart all over the area. These are then surrounded by sheet-piling, to prevent the soft soil escaping. Stones, concrete, etc., are then rammed in between the piles; the heads of the piles are cut off at one level; sleepers are laid across and fastened to them, and on these massive planking of great thickness is placed, on which the building is erected.

Before the application of steam power to pumping, this system was very expensive, and another was introduced into this country by a Swiss architect, named Labelye, and was first used in the erection of old Westminster Bridge, which was commenced in 1739.

The method adopted by Labelye (which, however, did not prove a good one) was the using of a *caisson*, or large water-tight chest (the word "caisson" meaning a large box or *caisse*). The bed of the stream was first carefully levelled by dredging. Strong frames of timber were then constructed, having upright sides like those of a box. These were floated over the place where the piers were to be built, and the masonry of each pier was commenced inside the caissons. When the first course was laid and cramped together, water was admitted by sluices into the caisson, which then sank. The bottom was not, however, found to be sufficiently level; the sluices were therefore closed, the water was pumped out of the caisson, and it was floated again. The ground was then again dredged and levelled, and this operation was performed three times before the mass of stone settled on a level bed. The pier was then built on this foundation, after which the sides of the caisson were removed and used for the next pier. Blackfriars Bridge, erected in 1760, was also built by caissons. In both these cases, however, the foundations proved failures, and both of the bridges have been removed, and that at Westminster is replaced by the elegant structure designed by Mr. Page, completed in 1862; and the new Blackfriars Bridge was, it will be remembered, opened by Her Majesty in person on the 6th of November, 1869.

Hitherto we have spoken of wooden piles, and before proceeding to mention those formed of iron, which are now so much used, it is deemed advisable to give the student some little information concerning piles and pile-driving. The piles, then, are squared beams of timber pointed at the bottom. The timber used for this purpose is oak, beech, fir, and larch. The piles are bound at the top by strong iron hoops, in order to prevent their being split by the force of the blows which drive them down; they are also protected at the bottom by iron shoes. When the piles are to be placed singly, the point is pyramidical, that is, cut to a *square* point (Fig. 2); but for sheet-piling the ends are cut *flat* (Fig. 3), so as to present an *edge*

* John Rennie was born at Phantassie, in East Lothian, in 1761. His early education was obtained in the parish school of East Linton, and he subsequently learned mathematics at Dunbar. He was for some time a workman in the employ of Mr. Andrew Meikle, an ingenious Scotch mechanic, who in 1787 invented the threshing machine. After attending various lectures on Natural Philosophy and Chemistry, he was taken into the employ of Messrs. Boulton and Watt, near Birmingham, and soon displayed such mechanical genius that Watt, in 1789, entrusted him with the direction of the construction and fitting up of the Albion Mills, London. His improvements in millwork were so striking that he at once rose into general notice as an engineer of great promise, and the thorough efficiency of his workmanship greatly contributed to his fame. To this branch of engineering he added, in 1799, another—the construction of bridges; and, amongst numerous others, he built Waterloo and Southwark bridges over the Thames, the latter built of cast-iron arch girders resting on stone piers. He also drew up the plans for London Bridge, which was not, however, commenced until after his death. In addition to numerous bridges, the London Docks, the East and West India Docks at Blackwall, with their goods sheds, the Hull Docks, the Prince's Docks, Liverpool, and those of Dublin, were all designed and wholly or partially executed under his superintendence. Besides the Plymouth Breakwater, Rennie planned many improvements in harbours and dockyards in Portsmouth, Chatham, and Sheerness. He died in October, 1821, and was buried in St. Paul's Cathedral.

rather than a point, and this edge, too, is a little slanting, that is, the triangular face is a little longer at one side than the other. (This has already been referred to in lessons in "Technical Drawing," but is here repeated in order to render the instruction as clear as possible.) The purpose of this is, that as the pile is being driven down, it will have the tendency *towards* the last pile which has been driven, and so a closer wall of piles will be formed. When sheet-piling is constructed, one pile is placed at each end of the required width, and a few others at intervals. These are called *guide* piles, and to these horizontal timbers are attached, called *wales*, which guide the rest of the piles, so that they may be placed in a straight line.

Piles are forced into the ground by pile-drivers or engines. The subject of these lessons precludes any lengthened description of such machines; it will be sufficient to say that a pile-driver consists of vertical guide-bars, between which a weight called the "monkey" is drawn up, either by a number of men or by steam power, and is suddenly released, when its weight descends like a huge hammer on the head of the pile, which in this way is driven into the soil. Nasmyth's steam pile-driver consists of a guide-bar, with the required machinery for hoisting the hammer, etc. This hammer is an important application of Nasmyth's steam-hammer. The "monkey" is attached to the piston-rod, working, as in the steam-hammer, *downwards* from the cylinders; it acts in an iron guide-bar, resting on the top of the pile which is being driven, the steam being led from the boiler to the cylinder by jointed pipes, which allow of the motion as the pipe sinks. Another important pile-driver, which was first used in the construction of St. Katherine's Docks, London, is the atmospheric engine, which is worked by an air-pump and a steam-engine.

Fig. 1.

Fig. 3.

Fig. 4.

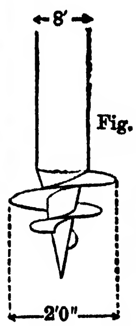


Fig. 5.

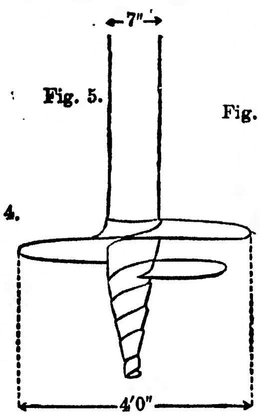
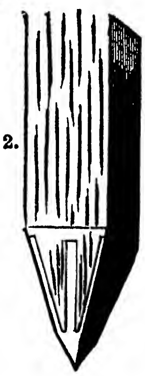


Fig. 2.



We shall have an opportunity of entering at greater length into the construction of those important engines in another series of lessons, and at the same time give some illustrations of them. When piles have only been used for a temporary purpose they are either cut off at the level of the ground or are drawn up; the latter plan, however, must always be adopted with great care, lest the vacuum caused by the withdrawal of them should weaken the foundation. Piles of cast iron were first employed in the construction of Bridlington harbour. The piles used in this work were formed of plates of iron, so contrived at the sides that each pile was united by a dove-tailed joint with the adjoining one. In 1822 Mr. Ewart took out a patent for iron piling, and the success of those employed by him emboldened others; eventually cylindrical iron piles were introduced, and are now largely employed.

These vary, according to the nature of the work, from three to seven feet in diameter. They are first lowered into the water, and driven as far as they will go without great difficulty into the ground; a quantity of clay is then placed around the outside of them, for the purpose of preventing the water forcing its way underneath the bottom. The water is pumped from the inside, and the workmen then descend into the cylinder and dig away the soil, which they send up in buckets, thus literally undermining the cylinder, which then sinks either by its own weight or by additional pressure. The pile is formed of parts, and at the top of the first part are flanges, which also exist at *both* ends of the other section. As one part sinks, another is bolted on to it, until the required depth is reached. On the ends of these cylinders the platform of girders and planking is constructed.

The screw-piles, introduced by Mr. Mitchell, are admirably adapted for loose, movable, and even sandy soils, and have been found very useful in situations where all other means have failed.

These piles are of wrought iron and are hollow, and terminate at their lower end in screws of various shapes (see Figs. 4 and 5). They are screwed down into the bed of the river or the bottom of the sea until the pile is firmly fixed; their heads are then connected by sleepers, and the superstructure raised upon the base thus formed. The lighthouse on the Chapman Sand, in the mouth of the Thames, is built on such piles seven inches in diameter and about forty feet long; the blade of the screw, which is of cast iron, is four feet in diameter. They are screwed down to the depth of about thirty-seven feet; on their heads iron girders, braces, etc., are bolted; and on these the lighthouse, which is entirely of wrought iron, is erected. The piles are seven in number, one driven in the centre, and the others at equal distances around it.

The plan which was adopted by Mr. Page, C.E., for getting in the piles of the new bridge designed by him at Westminster, described by Mr. Ashpital, is so novel and important that no course of lessons could be deemed complete without a slight description of it.

Rows of strong elm piles, about thirty feet long, are driven into the bed of the river, passing first through the gravel, which is about four or five feet thick, and then going about twenty feet into the London clay. There are about 140 or 150 piles to each pier, ranged alternately in threes and fives; around these a range of cast-iron piles is driven, about four feet apart. These are round, fifteen inches in diameter, and have strong grooves cast on each side of them; they, however, go into the clay only ten or twelve feet. Into these grooves large plates of iron, which the engineer calls "plate piles," are fitted, and driven down between the piles; they go about ten feet into the blue clay, and extend about a foot or two above the natural bed of gravel. Upon these is a series of slabs of granite, placed edgewise, retained in their places in the following manner:—

The bottom rests on the plate-piles, the edges are secured to the round iron piles, and the tops to the other masonry; the plate-piles are secured together by two sets of ranges of iron rods, passing through the pier and tying them together; these are all fixed by the divers. It will be seen, therefore, a sort of case or box is made, which surrounds the wooden piles on all sides; the loose standing mud is then dredged out, and the case filled up solid with hydraulic concrete, in which, of course, the piles are embedded, and the whole forms one solid mass to about a foot above low-water mark. At this level the tops of the piles are cut off, and on each top a stone, 2 feet square, and 1½ feet thick, is bedded, the spaces between which are again filled in with concrete. The gravel is then dredged out around the pier on the outside of the case, and the space also filled with concrete. It has been urged that the steamers would come into collision with the round piles, and break them so that the granite slabs will escape, as it were, and fall into the river. This, however, cannot be as long as the concrete remains in its place, as the top of the slab is secured by the masonry, and the bottom would not be accessible. It was, however, provided that the piles should be protected by floating booms, to prevent the chance of collision, and to act as safeguards for the steamers as well as the bridge.

THE STEAM-ENGINE.—I.

By J. M. Wigner, B.A., B.Sc.

PRIME MOVERS — SOURCE OF THE POWER — MECHANICAL EQUIVALENT OF HEAT — PROPERTIES OF STEAM — THE BOILER—WAGON, CORNISH, FLUE, AND TUBULAR BOILERS —SUPERHEATER.

In early times the advance of civilisation rendered the employment of machinery almost a necessity, and the need of some prime mover, other than the power of man, soon began to be felt. The force of the wind, and the power developed in running streams, would be the first to suggest themselves, and were early employed. A great inconvenience, however, attended the use of these agents, as they were uncertain and irregular in their action. A long-continued drought would so far reduce the level of many streams, that any hydraulic contrivances which had been set in motion by them would stand idle and useless, however much they might be needed. The uncertainty of the wind was also proverbially great, and a calm might occur just at the time when the machinery was required to act. The power of animals was, of course, in these cases, turned to account; but here again inconvenience and difficulty were experienced. The animals had to be fed and tended whether any work were required or not—thus entailing constant expense. Attention was, therefore, very naturally turned to the discovery of some source of power which should be certain and uniform in its action, well under control, and, withal, economical in its employment. The power which has up to the present time most perfectly succeeded in carrying out these various conditions is that of Steam. Many other prime movers — among which may be mentioned Electricity, Heated Air, and Gas—have at various times been suggested, and tried with varying degrees of success. None of them have as yet exceeded, or even equalled the force of Steam for all general purposes; but it is the opinion of many who are best competent to form a judgment on such a subject, that some of these will ultimately take the place that steam now occupies, and that the steam-engine will thus become among the things of the past. Be this as it may, the undoubted fact is that in the present day steam is all but universally adopted as the moving power in all our factories, large and small; and there is scarcely any article that we employ in our daily life, but in some stage or stages of its manufacture has been operated upon by its agency.

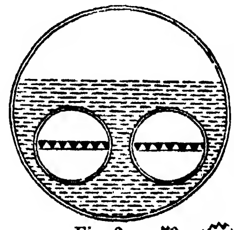


Fig. 2.

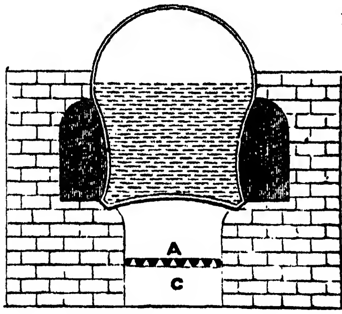


Fig. 1.

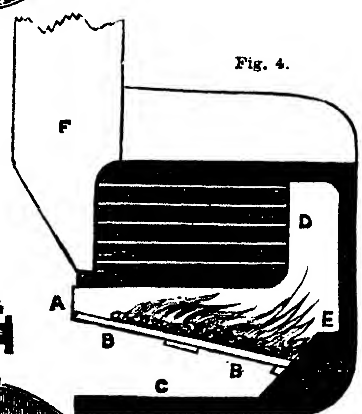


Fig. 4.

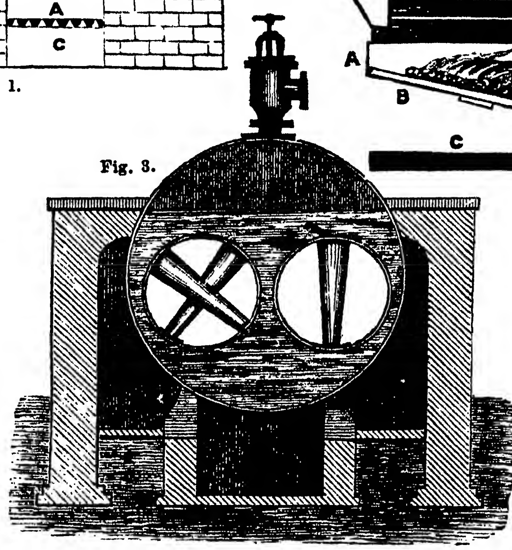


Fig. 3.

Even before the Christian era the attempt was made by Hero, the well-known philosopher of Alexandria, to drive an engine by the power of steam issuing from two small apertures, much in the same way as the hydraulic machine, known as Barker's Mill, is set in motion by the reaction of the water as it issues from openings in the two arms.

A scientific toy, acting on precisely the same principle, was some time since brought out under the title of "The Little Marvel" steam-engine, and was sold in large numbers.

*6—N.E.

It would be very interesting and instructive to trace the gradual development of the steam-engine from this, its earliest germ, down to the present time, but this would be foreign to the scope of the present papers, which is to furnish a practical description of its construction and action. We must, however, pay a passing tribute to James Watt, to whom more is due than to any other of the almost numberless engineers who have made or suggested improvements. In fact, we may say that, in most of its essential features, the steam-engine of the present day is the same as completed and perfected by Watt.

We must first inquire into the actual source of the power produced by the steam-engine; for it must be carefully remembered that no machine can *create* force—all that it can do is to control or modify its action. The source of the power, then, must be sought for in the fuel consumed in the furnace. As was explained in our lessons on Heat in The Popular Educator, heat and force are to a certain extent mutually convertible.

Illustrations of the conversion of force into heat are familiar to almost every one. We have a practical exemplification of it every time we strike a lucifer match, and, by the friction, generate sufficient heat to ignite the inflammable compound with which it is tipped. We are not, however, so familiar with the fact that heat may be converted into mechanical force. Such, however, is the case; and as the result of a long series of experiments, very carefully conducted by Dr. Joule and others, we learn that the amount of heat required to raise 1 lb. of water 1° Fahr., is sufficient to exert a mechanical force equal to raising a weight of 770 pounds to a height of one foot.

Every pound of coal or other combustible consumed in a furnace is capable of performing a certain definite amount of work, and the steam-engine may therefore be defined as "a machine in which the motive power of heat is utilised and made to accomplish any desired work." The problem to be solved is to discover in what manner the largest portion of this heat may be rendered available, and most of the improvements made in its construction have this as their aim.

At present, however, we cannot consider this problem as by any means satisfactorily disposed of, for, even in our best constructed machines, the actual work accomplished is seldom, if ever, more than one-eighth of the theoretical amount, and in the large majority of cases it falls considerably below even this. This subject is, of course, one which demands and has obtained much attention from practical men. One great cause of the waste appears to be that the extremes of temperature in the boiler and condenser are not sufficiently removed from one another. The greater this interval, the greater is the power obtained; in the engine, however, it is seldom above 200°; for although the temperature in parts of the furnace is frequently 3,000°, that of the steam is seldom much above 300° or 350°, there being practical difficulties in the way of employing it at a higher temperature.

If we take a vessel of water, and apply heat to it, the tem-

perature will gradually rise till it reaches 212°. At this point, if the vessel be an open one, it becomes stationary, and bubbles of invisible vapour, or steam, are formed at the surface exposed to the source of heat. These rise through the liquid, causing ebullition, and then escape into the air, where they soon become partially condensed, and are thus rendered visible. If the water be contained in a close vessel, the pressure of the steam generated gradually increases, until at last, if no escape be provided, it bursts the vessel.

By allowing the steam to enter an empty vessel, we find that it occupies a very large space as compared with the water from which it is produced, the increase in bulk being rather more than 1,700 times. As an easy mode of remembering this, we may state it thus :—A cubic inch of water, when converted into steam at the ordinary pressure of the atmosphere (15 lb. per square inch), occupies the space of a cubic foot. If the pressure be increased, the volume will be diminished in a corresponding degree ; thus the steam produced from a cubic inch of water will occupy only half a cubic foot when at a pressure of two atmospheres. On removing this pressure, it will at once expand. We see, then, that dry steam—that is, steam when above the point at which it is condensed—possesses the properties of an elastic gas, and it is to these properties, and to its great increase in bulk compared with that of the water from which it is generated, that we owe its employment in the engine. It may be well here, as a caution, just to remind the student that true steam is an invisible gas. That which we see issuing from the funnel of an engine or the spout of a kettle, is in reality partially condensed steam, that is, minutely divided particles of water suspended in the air.

We must not imagine that it is sufficient merely to raise the water in the boiler to a temperature of 212°, and that then it will at once be converted into steam. Were this the case, no vessel would be strong enough to withstand the sudden pressure thus produced, for the water would, on attaining the boiling-point, explode with a violence almost equal to that of gunpowder. The real fact is, that a large amount of heat is absorbed in the conversion of water into steam. If we take any vessel containing water at a temperature of 32°—that is, just at the freezing-point—and having placed a thermometer in it, expose it to a uniform source of heat, we can easily ascertain the exact time it requires to attain the boiling-point. Now let the heat continue uniform, the water will slowly boil away and be converted into steam, and we shall find that the time required to evaporate all the water is five and a half times longer than was taken to raise it from the freezing to the boiling point. The temperature of the steam has, however, at no time exceeded 212° ; it is clear, therefore, that this additional quantity of heat has all been stored up or rendered latent in the steam.

This may easily be proved. If we close the vessel, and allow the steam to pass along a pipe into another vessel filled with ice-cold water, we shall find that it has sufficient heat in it to raise five and a-half times its own weight of water to the boiling-point.

Having in this way just explained the more important properties of steam, so far as they relate to the engine, we must proceed practically to explain the mechanism and action of the different varieties of engine generally employed. To do this, the simplest plan will be first of all to explain in detail the construction of some one form, which may, to a certain extent, be regarded as a typical form, and then to trace the various deviations from this, which are rendered necessary by the different requirements of each particular case. The engine which we shall select for this detailed description is that technically known as a Double-acting, Condensing, Beam Engine; the meaning of these terms has been explained in the papers on this subject which have already appeared in THE POPULAR EDUCATOR, and will shortly become more apparent.

From what has been said, it is clear that the first requisite is a vessel in which the water may be contained for conversion into steam. This is technically known as the boiler, and must of necessity be so made as to be water-tight, and of sufficient strength to resist the outward pressure of the steam. It must, further, have such a form, that heat may be easily and economically applied to it. The construction of the furnace is thus intimately connected with that of the boiler, and, as we shall see, the utmost variety exists in the forms given to the two. The object sought is the means of generating the largest amount of steam with the smallest expenditure of fuel; economy of space is also in many cases an important requisite, and hence the form given to the boiler depends partly upon the special exigencies of the case. There are three main classes of boilers, viz., land, marine, and locomotive boilers. The two first-named are stationary, being usually firmly fixed in the position they are intended permanently to occupy. Space is usually more valuable in marine boilers, and hence special arrangements have to be made, even at the expense of an increased expenditure of fuel in proportion to the work accomplished. At the present time, however, the construction of land boilers is, in many respects, becoming more closely assimilated to that of those intended for marine use.

The form known as the "wagon" boiler, and represented in Fig. 1, was introduced by Watt, and for a long time was regarded as a standard form. Ultimately, however, it gradually fell into disuse ; and thereafter the "Cornish" boiler, a section of which is shown in Fig. 2, was perhaps the one most generally employed.

It consists of a cylindrical shell, usually made with flat ends, and has one or two large internal circular flues, in which the furnaces are placed; the hot air, having passed along these, returns by flues made in the surrounding brickwork at the sides or bottom. The cylindrical form is much better calculated to resist the strong internal pressure to which boilers are subjected. In other forms strong internal stays are nearly always introduced, to impart additional strength. The internal flues are firmly riveted to the ends, and materially add to the strength of the boiler.

There are some objections to this form, the main ones being that the space for the furnaces is rather limited, and a sufficient slope cannot well be given to the bars. The tubes, too, unless carefully strengthened, will sometimes collapse from the pressure; but these difficulties may be overcome, and the boiler is reckoned one of the best for ordinary circumstances.

The plan of allowing the flame and heated gases from the furnace to play outside tubes containing the water, instead of passing through tubes filled with it, has been adopted in many instances with beneficial results. An application of this principle was patented by Messrs. Galloway, and became considerably employed. Conical tubes are made to pass right through the central flues, beyond the combustion-chamber and the fire-bridge, on the plan shown in Fig. 3, which represents an ordinary Cornish boiler with these tubes, which are known as "Galloway Tubes," fitted to it. Owing to their conical form, the flange at the lower end will pass through the opening in the upper side of the flue, and thus save much trouble in the fixing. They are found to serve as a support to the flues, rendering them much less liable to collapse, and at the same time they afford increased and very effective heating surface, and improve the circulation of the water in the boiler. This latter is found to be a very important point. When two furnaces exist, they are usually fired alternately, and in this way the production of smoke is found to be considerably lessened.

The boilers employed for the earlier marine engines were of the class known as flue boilers, and they attained a high degree of efficiency. In these the flues were wholly internal, so that they were surrounded on all sides by a thin layer of water, and the products of combustion were thus made to circulate through the boiler before escaping into the chimney. As will easily be understood, the great object required to be obtained is to absorb as much as possible of the heat, without rendering the draught too feeble. When the heated air escapes into the chimney at a very high temperature, there is, of course, a corresponding waste of heat; the object, therefore, in having these long flues is to enable the water in the boilers to take up as much heat as possible. It will easily be seen that when the flues are internal, that portion of heat which is usually absorbed by the brickwork, and which is by no means inconsiderable in quantity, is saved.

A tubular boiler is, however, now nearly always employed in marine engines. In this the heated products from the furnace, instead of passing along one large flue, are broken up into a number of small streams, which pass through a series of tubes, and thus give up nearly all their heat to the water. In this way it is found that a great economy of space is effected, the heat being much more rapidly abstracted from these small streams. Sometimes multi-tubular boilers are constructed on a

plan very similar to the Cornish boiler already figured. The front part of the flue is fitted with a sloping grate, and serves as a combustion-chamber, which extends only part of the length of the boiler; at the back of this is placed the fire-bridge, against which the flames first impinge. The rest of the flue is replaced by a series of small tubes about two and a-half inches internal diameter. These are, of course, firmly fixed into a tube-plate at each end, so as to render the joints water-tight. A packing of wood is often introduced for this purpose.

Care must be taken not to place the tubes so close together as to impede the circulation of water, as it has sometimes been found that the additional heating surface thus attained is more than counterbalanced by the impaired circulation; in these cases an increased production of steam has been caused by removing a few of the tubes.

With a boiler of this form a return flue is usually unnecessary, and the smoke is allowed to pass directly into the chimney; much of the cost and labour of setting in brickwork is therefore dispensed with.

Another form of boiler, now very frequently employed in steam-vessels, is represented in Fig. 4. In this the furnace passes from end to end of the boilers, and the tubes are placed above it, so that the smoke passes back again along the boiler before escaping into the chimney. A is the furnace-door, B B the fire-bars, which slope away from the front, so that the fuel gradually passes along to the further end, as fresh is supplied in front. In this way the smoke produced, when the furnace is coaled, has to pass over the surface of the highly incandescent fuel at the further end before it reaches the flues, and thus it is to a considerable extent consumed. The gases then strike against the fire-bridge, E, and pass into the space D. From this they travel along the horizontal tubes till they escape into the flue, F. In this way there is but little waste of heat: even the ash-pit, C, is, as will be seen by the figure, within the boiler, so that the heat from it is not wasted.

The tubes in this boiler are, it will be observed, entirely surrounded by water. Sometimes another set is placed above these, so as to be in the steam space, and these serve to raise the temperature of the steam, and thus render it more perfectly dry. This second set is technically known as the "superheater."

Steam in most of its properties resembles a gas, and, like any gas, expands on the application of heat to it. If, then, the steam be exposed to a higher temperature, either its volume or its pressure will be increased, and a greater mechanical effect may therefore be obtained from it. Another advantage is also obtained by superheating the steam. Under ordinary circumstances, when the steam is not at a very high temperature, it is partly condensed by contact with the cylinder and other working parts; and hence there is a deposit of water in them, and a corresponding loss of power. By superheating the steam this is guarded against. Some years ago the tendency was to superheat the steam as much as possible. It is found, however, that if its temperature be raised above 315°, the packing of the stuffing-boxes is liable to become charred, and the oil or other lubricant used in the engine to be injured. The practice, therefore, seems to be gradually diminishing, and is not usually carried much beyond the degree that is requisite to render the steam thoroughly dry.

Very many different forms of superheater have been proposed, and tried with varying degrees of success. The usual plan is to cause the steam to pass through a series of tubes placed at the lower part of the chimney, so that the heat employed is that which would otherwise escape with the smoke. It is not found that when fresh fuel has to be employed, any advantage is gained by employing it in superheating the steam, instead of applying it to the boiler in the ordinary manner.

ELECTRICAL ENGINEERING.—III.

BY EDWARD A. O'KEEFFE, B.E., A.S.T.E.,
Demonstrator in Electrical Engineering, City and Guilds of London Technical College, Finsbury.

INTRODUCTORY (*concluded*).

THE motor is a machine peculiarly adapted for facilitating the distribution of energy. Where a small amount of power is wanted at some distance from the generating source, electricity appears to be the most convenient and most economical agent by means of which the necessary transfer of energy can be accomplished. Where a large natural supply of energy already exists—as, for instance, in the case of a waterfall—the motor may often be used with great advantage to do useful work at a considerable distance from the fall. The current which supplies the motor is conveyed to it through copper wires from a dynamo situated at the fall. The dynamo itself is driven by means of turbines or a water-wheel.

The dynamo is of later origin than the motor, and depends on the converse principle to that which governs the latter. In the motor, electrical energy in the form of a current is transformed into mechanical energy which does work; in the dynamo, mechanical energy is transformed into electrical energy in the form of current. The motor depends on the principle that a coil of wire, in which a current is flowing, will make a magnetic pole placed in its vicinity move towards it. The dynamo depends on the principle that a current will be generated in a coil of wire if a magnetic pole be moved in its vicinity. This great discovery was made by Faraday in 1831. Œrsted had discovered that a wire, or coil of wire, carrying a current, acted upon a pivoted magnetic needle placed in its vicinity, and forced it to take up a position at an angle to the magnetic meridian, and forced it to retain this position as long as the current lasted. When the current ceased the needle returned to its original position pointing north and south. It occurred to Faraday that the converse might also be true; *i.e.*, if a magnet be placed in, or in the vicinity of, a coil of wire, a current might be generated in that wire. He took a coil of wire, and connected its ends to the terminals of a galvanometer which would show the presence of a current if any existed in the wire. He then placed a magnet in the coil, but found that no current was generated; and the same result was obtained however strong the magnet was, or however sensitive the galvanometer. While making this experiment, he noticed that at the moment when he placed the magnet in the coil, the galvanometer gave a momentary deflection to one side and immediately returned to zero, and that when he withdrew the magnet it gave a similar deflection to the opposite side. These deflections could only be due to currents in the coil, and these currents were evidently only momentary. On further investigation he found that these currents lasted only as long as the motion of the magnet lasted; when that motion ceased the current ceased. The strength of the current depended upon the strength of the magnet, and the speed with which it was moved; while its direction depended upon the kind of pole which was moved, and the direction in which that movement took place. These currents are known as *induction currents*, and Faraday also discovered another and most important method by which they could be generated; namely, by the action of an independent current. He wound two coils of wire side by side on a wooden cylinder, connecting the ends of one coil to the terminals of a galvanometer, and the ends of the other to the poles of a Voltaic battery. The result which he obtained was somewhat similar to that just described. No matter what strength of current was sent through the one coil, the galvanometer showed that no current was passing through the other; but at the moments when the current started and when it ceased the galvanometer showed that momentary currents were generated, which were equal in strength, but opposite in direction. The coil in which the permanent current from the battery flows is known as the *primary coil*, the other as the *secondary coil*. He also found that any change in the strength of the current in the primary coil produced a momentary current in the secondary; and, carrying his investigations a little farther, he found that if he took two coils of wire, in one of which a permanent current was flowing, and moved them near one another, a current was generated in the secondary coil, *which lasted as long as the relative motion of the two coils lasted*. When motion ceased, the induced current ceased also. The coil in which the permanent current was flowing behaved in every respect as if it were an ordinary permanent magnet.

There appears to have been some doubt expressed at that time as to whether the effects above described were due to electricity, and perhaps it would be as well to close our account of his work on this subject with Faraday's own words:—"The various experiments of this section prove, I

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think, most completely, the production of electricity from ordinary magnetism. That its intensity should be very feeble and quantity small, cannot be considered wonderful when it is remembered that, like thermo-electricity, it is evolved entirely within the substance of metals retaining all their conducting power. But an agent which is conducted along metallic wires in the manner described, which, whilst so passing, possesses the peculiar magnetic actions and force of a current of electricity, which can agitate and convulse the limbs of a frog, and which, finally, can produce a spark through charcoal, can only be electricity."

This great discovery of Faraday's—that the movement of a magnet near a coil of wire, or the movement of the coil near the magnet, is sufficient to generate a current in the coil—revealed a new method by which currents could be generated. In 1833 Pixii constructed a machine in which a bobbin of wire was rapidly rotated near the poles of a powerful steel magnet which induced currents in the coil. This bobbin has received the name of the *armature*, and this type of generator is known as the *magneto-electric machine*. These currents differed in two important points from those supplied either by Voltaic cells, or thermo-electric generators; the cells and generators supplied fairly constant and *continuous* currents, whilst those supplied by the machine of Pixii were anything but constant, and what is of far more importance, they were *alternating*—*i.e.*, the direction of the current was regularly reversed as the coil was spun round. The first of these difficulties has since been overcome by winding the armature so as to be made up of a large number of turns of wire, in separate sections. The difficulty of the alternating currents has also been solved by fixing on the axis of the armature an arrangement called a *commutator*, which forces all the currents generated in the armature to flow in the same direction. Most of those little instruments sold as medical machines for giving "shocks," are Pixii machines constructed in a convenient form. The fact that the current is alternating is the reason why the shock given by such a small machine is so severe.

Larger machines of this class were built, but the currents which they generated were small when compared with the cost of the apparatus and its bulk. The next important advance in dynamo machinery was made by Wilde, who substituted powerful electro-magnets for the permanent steel ones which had previously been used. The current to excite these electro-magnets was supplied by an independent magneto-electric machine, and very powerful currents were generated by this means.

In 1867 both Siemens and Wheatstone suggested that these electro-magnets might be excited by the current generated in the machine itself, thus dispensing with the auxiliary magneto-electric machine used by Wilde; and this type, together with the many modifications which have since been introduced into it, is known as the *dynamo-electric machine*. Since that date the dynamo machine has developed so rapidly, that at the present time it has arrived at such a stage that it is not only thoroughly reliable, but highly efficient.

All these continuous current dynamos are *reversible;* that is to say, they can be used as motors if supplied by an independent current.

The dynamo, in conjunction with the motor, is capable of doing a considerable amount of work at practically any distance from the central station where the power is supplied, and is capable of doing it in a fairly economical manner. It is not surprising then that many men have attacked the problem of how to drive trains and tramway carriages by its means; and though their efforts have not been crowned by complete success, still the electric railway from Portrush to the Giant's Causeway in the north of Ireland, and the one along the sea shore at Brighton, show that those efforts have been far from useless. In the case of a train it was necessary to have a powerful motor placed in the engine and attached to the driving-wheel. When the current was allowed to pass through this motor it expended its energy in doing the work necessary to drive the train. This current is generated by a dynamo machine situated at some convenient position along the line, and is carried to the motor either along the rails—in which case they must be insulated so as not to waste any of it by leakage—or it must be carried along an independent insulated conductor, and communicated to the motor by a metallic brush attached to the engine and sliding along this conductor as the train moves. In the case of tram-cars the motor is also used, but it has been found advisable to supply the current in a different manner. *Accumulators* or *secondary batteries*, carried in the tram itself, are found more convenient for this purpose, these accumulators being charged at the terminus by a dynamo machine. The necessity for using insulated conductors in the public streets is thus obviated.

Many attempts have been made during the present century to store up electrical energy so as to render it available at some subsequent time; and though several men partially succeeded, Gaston Planté was the first to solve the problem in anything like a commercial manner. His accumulator consists of two sheets of lead wound in the form of a spiral, but without touching one another, and immersed in dilute sulphuric acid. When a current is passed through this cell a film of dioxide of lead is formed on one of the plates, while the surface of the other is reduced to the state of spongy lead. While in this condition the cell is capable of giving a very powerful current for a length of time depending upon the state of the plates, and if the cell be in good condition it will retain its charge for a considerable time. In 1881 Faure, Sellon, and Volckmar introduced improvements in the Planté accumulator, which, with those which it has since undergone, render it invaluable in electrical engineering. No installation of incandescent lamps is complete without a set of accumulators; in fact, they play that part in an electric light installation which the gasometer plays in the common system of lighting by gas.

The transmission of sound by means of electricity involves principles which must be dealt with in detail. The *telephone* is extensively used in large towns for transmitting speech, but only for short distances; and though conversation has been carried on by its means over a distance of some hundreds of miles, still the subject of long-distance telephony must be looked upon as in its infancy, while at the same time it may be expected to spring to maturity with rapid strides in the immediate future.

Recent years have seen mighty changes wrought by electricity, which so readily assumes that form of energy which is most useful, while the continually increasing number of purposes to which it is being put, to some extent foreshadows the importance of the position which it must necessarily take in the coming higher civilisation.

PROJECTION.—V.

TO PROJECT A PENTAGONAL PRISM.

LET A B C D E (Fig. 61) be the plan, and $e\,{}^{d}_{c}\,a$, $e'\,{}^{d'}_{c'}\,a'$ (Fig. 62) the elevation when one of the long faces, A B, is at right angles to the vertical plane. Fig. 63 is the elevation, looking directly at the point E. The mode of obtaining this elevation has been shown in Fig. 40. The upper end of the axis is shown at g in the centre of the plan,* and its position in the elevation is at $f\,g$. Now it will be remembered that the ends of a right prism are equal and similar planes, parallel to each other,† these ends being united by lines at right angles to their surfaces; and it will therefore be evident, that projecting a prism is only repeating the process of projecting a plane. Thus let it be required to draw the plan of the prism when resting on A B, its axis at 45° to the horizontal, and parallel to the vertical plane. It has already been shown that the axis is parallel to the edges of a prism; consequently, as the axis is at 60°, so will be the edges. Therefore, place the line $a a'$ (Fig. 64) at 45°, and on this line construct the elevation of Fig. 61; project the ends (Fig. 65) by dropping perpendiculars from the points in the elevation (Fig. 64), and intersecting these by horizontals from the

* To find the centre of a regular polygon:—Bisect two of the angles of sides which adjoin each other, and the point where the bisecting lines meet will be the centre.

† When the planes forming the ends of the prism are at right angles to the long sides (that is, so that if the prism stands on one of the ends, the long sides may be vertical), it is called "a right prism." When the planes of the ends are slanting to the length of the prism, it is called "oblique." In these lessons all prisms are assumed to be "right," unless otherwise expressed.

corresponding points in the plan of Fig. 61. Unite the points of these two plans by lines representing the long edges of the prism, which will then be seen to be parallel to the vertical plane (Fig. 65).

Fig. 66 shows the prism when the axis is at 45° to the horizontal, and 30° to the vertical plane. In this figure it will only be necessary to place the plan of Fig. 65 at the required angle with the intersecting line, viz., Fig. 67; then perpendiculars drawn from the angles, intersected by horizontals drawn from the corresponding points in the elevation, will give the projection.

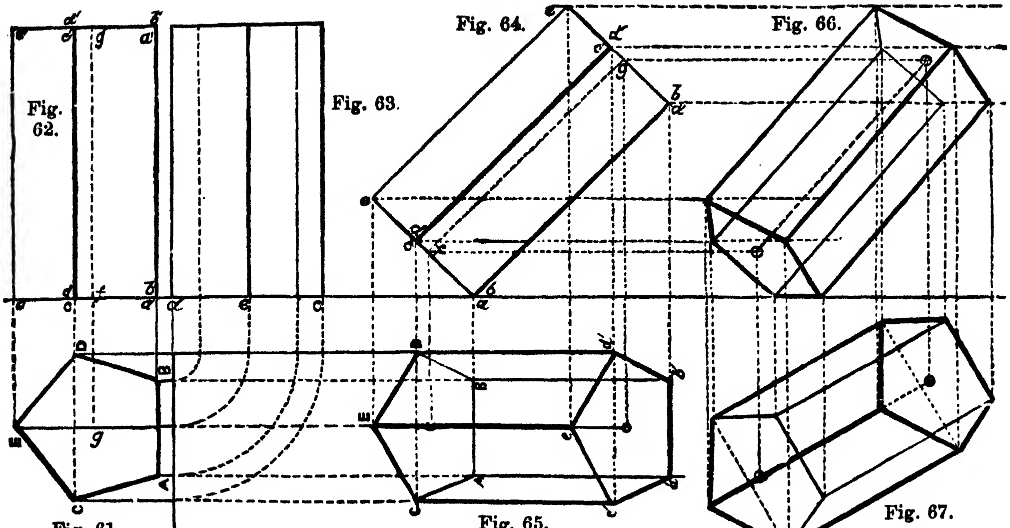


Fig. 61. Fig. 62. Fig. 63. Fig. 64. Fig. 65. Fig. 66. Fig. 67.

OF PYRAMIDS.

A pyramid is a solid which stands on a triangle, square, or polygon, and terminates in a point, all its sides being, therefore, triangles.

The axis of a pyramid is the line joining the centre of the base to its summit, called the apex. When the axis rises from the centre of the base, and is perpendicular to it, the sides will be all equal triangles, and the solid is called a right pyramid. When the axis is not at right angles to the base, the pyramid is called "oblique." When the upper part of a pyramid or cone is cut off, the solid is said to be "truncated."

Fig. 68 is the plan, and Fig. 69 the elevation of an hexagonal

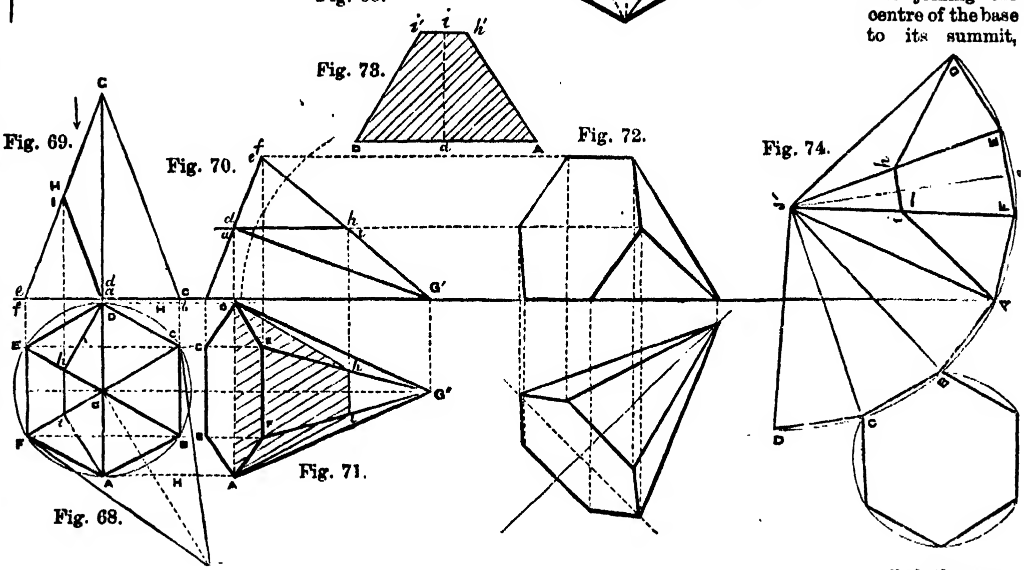


Fig. 68. Fig. 69. Fig. 70. Fig. 71. Fig. 72. Fig. 73. Fig. 74.

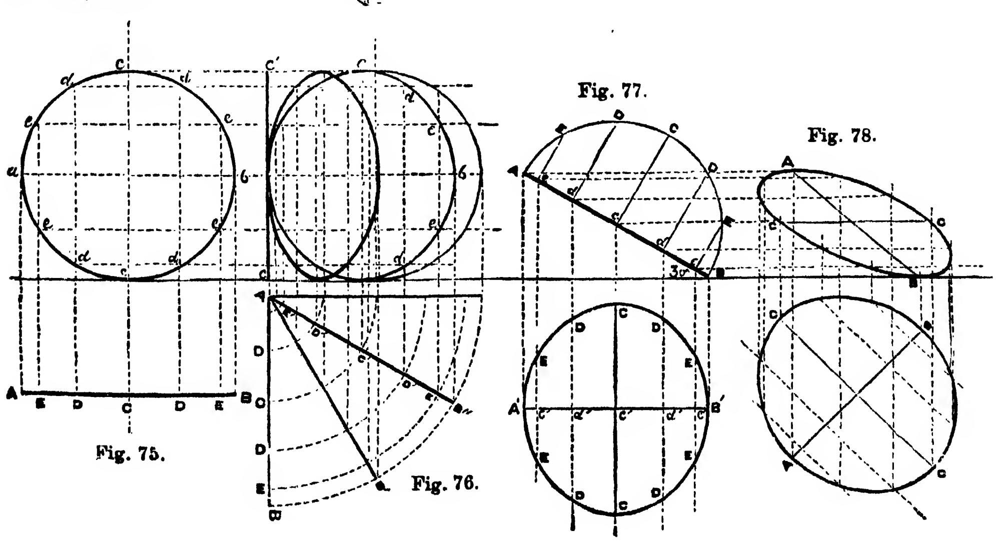


Fig. 75. Fig. 76. Fig. 77. Fig. 78.

pyramid when two sides of the plan, B C and E F, are at right angles to the vertical plane, and its axis vertical. Now let it be required to draw the plan of the pyramid when lying on the side B C G. The elevation (Fig. 70) will be precisely the same as in Fig. 69, altered only in position. It will be self-evident that if a pyramid stood on a plan, and, whilst resting on the line B C, it were gradually turned over until it should lie on one of its triangular faces, the widths F E, B C, and A D would remain the same, notwithstanding the change of position; for, supposing pieces of board were placed upright on the lines H H, the angles A, D would touch these "wooden walls" throughout the movement; but this is not so with regard to the widths from E to C, and from F to B, which are altered according to the position of the plane of the base in relation to the horizontal plane.

The points for the plan (Fig. 71) will therefore be found by producing the straight lines E C, F B in the plan, and intersecting them by perpendiculars from the corresponding points in the elevation. A line drawn from G in the plan parallel to the intersecting line, intersected by a perpendicular from G′ in the elevation, will give G″, which will be the plan of the apex.

Fig. 72 is the projection of the pyramid when lying on one of its faces, with its axis at 45° to the vertical plane. In order to test the student's comprehension of the foregoing lessons, this figure is left unlettered.

It is now required to find the true shape of the section *a d*, H I (Fig. 69). It will be evident that, as *a d* in the elevation represents A D in the plan (Fig. 68), A D will be the width of the section at its base. Therefore, draw A D (Fig. 73), and erect a perpendicular at its centre. Make this perpendicular equal to $\frac{d\ \mathrm{I}}{a\ \mathrm{H}}$, and draw a line through *i* parallel to A D. From $\frac{\mathrm{I}}{\mathrm{H}}$ (Fig. 69) draw a perpendicular cutting the radii F and E of the plan in $\frac{i}{h}$. Join *h i*, *i* A, *h* D. Then A D *i h* will be the plan of the section, or the view of it looking downward in the direction of the arrow. On each side of *i*, in the true section (Fig. 73), set off half the length of the line *i h* in the plan—viz., *i′ h′*. Join *h′* A and *i′* D, which will complete the form of the section.

The next step is to develop the covering of such a solid. It is hoped that, after the instructions already given, this will prove an easy task.

From G in the plan (Fig. 68) draw a line, G J, perpendicular to F C, and equal to the height of the pyramid ($\frac{d}{a}$ G). Draw F J, C J, which represents the section which would be bounded by a diagonal of the base and two of the *edges* (*not sides*) of the pyramid. With J F as radius, describe an arc (Fig. 74), and set off on it the lengths equal to the sides of the base. Join all these points to each other and to J′. On C B, or any other of the sides, construct a regular hexagon, which will complete the development of the pyramid and base. Bisect E F by the line $\frac{\mathrm{J}'}{e}$, and on this line set off the height, *e* I, on the elevation (Fig. 69), and through I draw *i h*. Join these points to each other and to A, D; this will give the section-line marked in the development.

PROJECTION OF CIRCLES AND CYLINDERS.

We now approach a branch of our subject which is of especial importance to engineers and metal plate-workers—namely, the projection of circles and cylinders, and their development. As, however, the previous lessons have gradually led up to this point, it is hoped that the student will have been so prepared for the subsequent studies that he will find but little difficulty in them.

Fig. 75 is the front elevation of a circular plane; and it will be seen that the plan of this is a mere line, A B, equal to the diameter of the circle. (The aperture in a child's money-box is the plan of the penny which drops through it.) To prepare this disc for projection, divide its circumference into any number of equal parts, as *a e*, *e d*, etc., and from the points *a*, *e*, *d*, etc., drop perpendiculars to cut the plan A B in the points similarly lettered. If now we rotate the disc so that its plan is at right angles to the intersecting line (Fig. 76), the elevation, too, will be a line, *c c′*, equal to the diameter. To project this circle, transfer the points C, D, D, and E, E to plan A B (Fig. 76). Let it then be required to find the forms of elevations when the plane of the disc is at 60° and 30° to the vertical plane. Place the plan at each of these angles, as A B′ and A B″. Taking A as a centre, describe arcs from the points in the plan to cut the plans A B′ and A B″ in C′ D′ E′. From each of these points draw perpendiculars, and from the points similarly lettered in the elevation draw horizontals. The intersections of these two sets of lines will give the points *c*, *d*, *e*, etc., through which the curve is to be drawn by hand in the first instance, but it may subsequently be inked by means of the French curve, or centres may be found from which parts of the ellipse may be struck.

The principle on which the projection of a circle is founded having thus been shown, Fig. 77 gives a simplified method. Let it be required to draw the plan of a circle when resting on one end of a diameter which is parallel to the vertical plane, the surface being at 30° to the horizontal plane. The line A B, placed at 30° to the intersecting line, will then represent the elevation of the disc. From the centre of this line, with the radius of the circle it is intended to project, describe a semicircle, and divide it into a number of equal parts, A E, E D, etc. From each of the points A, E, D, etc., draw lines meeting A B at right angles in the points *c*, *d*, *d*, *e*, *e*. Draw any line parallel to the intersecting line, and draw perpendiculars to it from A and B; then this line A′ B′ will be the plan of the diameter which is parallel to the vertical plane. The semicircle drawn on A B represents one-half of the disc lifted up until it is parallel to the vertical plane. The lines C *c*, D *d*, and E *e* thus show the distance which each of these points in the circumference is from the diameter A B. Therefore, from *e*, *e*, *c*, *d*, *d* in the elevation draw perpendiculars passing through the plan of the diameter A′ B′ in *e′*, *d′*, *c′*, *d′*, *e*. From these points set off on the lines drawn through them, and on each side of A′B′, the lengths *e′* E, *d′* D, *c′* C, etc., and through the points thus obtained the plan is to be drawn.

Fig. 78 shows the mode of projecting a circle when its surface is at 30° to the horizontal, and one of its diameters at 45° to the vertical plane. Place A B at 45° to the intersecting line, and on it construct the plan by measurement from Fig. 77. This is best done by drawing a line, C C, at right angles to the diameter, A B, and on each side of the intersection marking off the distances *c*, *e*, *d*, *d*. By drawing lines through these points at right angles to A B, and making them the same length as in the plan of Fig. 77, the points for the present figure will be obtained. From these points in the plan draw perpendiculars, and from the points correspondingly lettered in the elevation of Fig. 77 draw horizontals, and the intersections will give the points through which the projection of the circle is to be drawn.

MINERAL COMMERCIAL PRODUCTS.—V.

CALCAREOUS* SUBSTANCES.

THE metal *calcium* very readily oxidises and forms lime, which easily enters into combination with carbonic acid, forming carbonate of lime (the base of limestone, chalk, marble, and calc-spar), and with sulphuric acid and water to form gypsum. Carbonate of lime in its various forms is a most abundant substance, and of the most extensive use, whether in its native condition as stone for building, paving, statuary, and smelting, or in its preparations—mortars and cements, in glass-making, leather-dressing, bleaching, agriculture, and medicine.

Common limestone is found in almost every geological formation; compact and often crystalline in the older rocks, but generally loose and more earthy in the newer. It is abundant in nearly all countries, in varying qualities and degrees of adaptation to its numerous uses. In England it chiefly occurs in the rocks of the Devonian and Carboniferous series—mountain limestone especially—and in the Liassic and Oolitic systems. The dolomite or magnesian limestone belongs to the Permian group of rocks. The best kinds of limestones for building are those of Portland, Bath, Box, and Corsham, all of which are Oolitic, and the magnesian limestone of Notts and Yorkshire. The oolite of Bavaria furnishes a very fine lithographic stone; these stones are also supplied from older rocks in Canada, and from France, Greece, and Portugal.

Of ornamental limestones, those of South Devon are extensively worked. Some interesting varieties of the red, grey, and variegated marbles (so called) are obtained near Torquay. Many blocks are almost entirely formed of fossil corals, and

* That is, having the nature of limestone.

known as *madrepore* marbles. The Carboniferous rocks of Derbyshire are rich in ornamental limestones, the chief varieties of which are the *entrochal* or *encrinital* marble, *productal* marble, and *black* marble. The former of the first two is built up of the stony fragments of stone-lilies (*Encrinites*), whilst the latter is composed almost entirely of shells of the genus *Producta*. Other marbles of a like character are obtained in Staffordshire, Somersetshire, and Ireland. The Purbeck and Petworth marbles are limestones charged with the fossil shell *Paludina*, and hence are sometimes called paludinal marbles; they belong to the Purbeck and Wealden series respectively, and were formerly used extensively in ecclesiastical architecture.

The true marbles are altered limestones or dolomites. The finest is the pure white or statuary marble; others are red or yellow in colour, and either pure or streaked. They are firm in texture, finely grained, and susceptible of a beautiful polish; hence their use for ornamental purposes. Italy is pre-eminently a marble-producing country, and has of late years produced an average of 250,000 tons per annum of statuary marble. The best white marble is now obtained from Carrara, quarried in the Apennines where they approach the Mediterranean. India, Sicily, Spain, Ireland, the United States, and other countries also furnish it.

Coral limestone belongs to this group of mineral products. It is a recent formation, and the rock is sometimes used as a building stone in the South Sea Islands. Great numbers of these islands, as well as numerous others in the Indian Ocean, are themselves natural coral structures. Coral reefs are abundant in tropical seas and the North Atlantic and Pacific Oceans.

Marl, a mixture of clay with carbonate of lime, occurs as clay-marl, marl-clay, and shell-marl. It is procured from valleys which have formed the beds of lakes, and from the neighbourhood of existing lakes, and is useful as a manure. Calcareous sand, formed chiefly of crushed shells, and found on ancient and modern beaches, is also used in agriculture. Of such sand, 8,000,000 cubic feet are annually removed from the Cornish coast into the interior. The shelly deposits of the Crag formations, in the east of England, are similarly used.

Gypsum is a very valuable mineral, occurring chiefly in the New Red Sandstone and in Tertiary deposits, but also among earlier rocks. It is abundant in England, Ireland, France, Canada, Nova Scotia, and in many other places. Gypsum forms the plaster of Paris, of such utility in building and modelling; crystallised, it is met with in *selenite*, *satin gypsum*, and *alabaster*. The use of this last, for statuary and ornamental work, dates from the remotest times of Etruscan art. Statuary alabaster is obtained from the Miocene and Pliocene strata in Tuscany and in Egypt.

Limes, stuccoes, and cement, so indispensable in all building operations, are obtained from various carbonates. Pure carbonates make rich limes, which are such as set only in dry air; impure ones (with mixtures of clay) yield hydraulic limes, which possess the valuable property of setting in moist air, and even under water. The septaria or calcareous nodules in London Clay, at Sheppey, those procured at Harwich, the cement stones of the Lias at Whitby, and of the Speeton Clay of Yorkshire, the Lower Lias Limestone, etc., furnish suitable limestone for hydraulic cements.

SILICIOUS SUBSTANCES.

Another very important mineral substance is silica, which is a combination of oxygen with the metalloid silicium or silicon. The purest examples of silica are rock-crystal, quartz, and flint. The colourless crystals, especially the so-called Brazilian pebble, are much used for lenses. Quartz, which, crystallised, constitutes several of the gems, is an important constituent of granitic rocks; and, in the form of sand, it is the principal ingredient in all sandstones. Quartz, well powdered, is combined with fine clays in the manufacture of porcelain in China, as flint is also in Great Britain. Flints are irregular masses of nearly pure silica, occurring in nodules distributed in layers, in the Chalk formation especially. Reduced to powder, they enter into the composition of china, porcelain, and glass; and, whole, they furnish a rough building material.

Sandstones are of very various composition and of different degrees of hardness. They consist of silicious sands, often mixed with other substances, all cemented together by means of carbonate of lime, oxide of iron, silica, or clay. They are of all geological ages, the oldest being usually the most compact. When hard and coarse-grained they are denominated grits. If pebbles very largely predominate, they are called conglomerates, and these are either pudding stones with rounded pebbles, or breccia with angular fragments. The extremely hard and schistose grits are very useful for flag-paving. The best qualities of these are supplied from Forfarshire and Caithness. Millstones are obtained from the Millstone Grit of Newcastle, from Yorkshire, Belgium, France (especially at La Ferte), and Wurtemburg. They are also made from a silicious limestone near Paris, and out of lava at Andernach. For building purposes, the finest sandstone is quarried at Craigleith and other localities in the Carboniferous formations of Scotland. Good stone is obtained from rocks of the same age in Durham, Yorkshire, Derbyshire, etc., and from Queen's County and other parts of Ireland.

Silicious sands are much in request in the arts, as in building for mortars, in moulding and casting, and in glass-making. The most valuable for the last-named purpose are procured from Senlis in France, from the Isle of Wight, Lynn Regis, Aylesbury, and Reigate. *Rottenstone*, found in Derbyshire and elsewhere, is a decomposed silicious limestone, and is used for polishing. Bath brick, Tripoli powder, the polishing powder from Bilin, in Bohemia, the *Berg-mehl* of Sweden and America, and the French *tellurine*, are peculiar mealy forms of silica.

IGNEOUS AND METAMORPHIC ROCKS.

Granites, and their allied rocks, gneiss, mica-schist, and felstones, consist largely of silica. Their chief mineral constituents are quartz, felspar, and mica (white, green, or black). Felspar is a silicate of alumina and potash, or, in the case of *albite*, the white felspar of Cornish granite, of alumina and soda. Mica is a silicate of lime and alumina or iron. Where hornblende, a dark-green silicate of lime and magnesia, has taken the place of mica, the stone is called *syenite*. These rocks assume a structure termed porphyritic—that is, they are composed of crystals embedded in an amorphous matrix—and are highly valued for ornamental purposes. These latter, and white granite, are obtained from Cornwall and Devon, red and grey granites from Aberdeen and Peterhead, and a very hard and dark variety from Guernsey, the Malvern Hills, and Leicestershire. Granitic rocks are abundant in many parts of the world, Ireland, Norway and Sweden, India, and China among others; and Egypt is famed for its syenite and red porphyritic felstone. They furnish a durable and highly polishable building material, particularly well suited for bridges, quays, and monumental works. The coloured varieties are eminently adapted for ornamental purposes. *Mica* is often found in large crystals, which can be split up into plates and used as glass. This is the material known as Siberian glass, from the country whence it is supplied. *Talc* is a similar mineral, and is employed in the porcelain and crayon manufactures: it forms, besides, the French chalk. *Asbestos* is a fibrous variety of hornblende. It can be woven into a fire-proof cloth, and is also made available in open gas stoves.

PRINCIPLES OF DESIGN.—II.

By Christopher Dresser, Ph.D., F.L.S., etc.

EGYPTIAN ORNAMENT—GREEK ORNAMENT—EARLY CHRISTIAN SYMBOLISM.

In my former article I observed that ornamental forms in many cases make utterance of truths which are so far hidden as to be imperceptible to the untutored, and this utterance was illustrated by reference to the Egyptian lotus, which spoke to those for whom it was intended of coming plenty, and thus became first looked for with pleasure, then reverenced, and finally worshipped as the abode or personification of a god.

Egyptian ornament is so full of forms which have interesting significance that I cannot forbear giving one or two other illustrations; and of this I am sure, that not only does a knowledge of the intention of each form employed in a decorative scheme cause the beholder to receive a special amount of pleasure when viewing it, but also that without such knowledge no one can rightly judge of the nature of any ornamental work.

There is a device in Egyptian ornament which the most casual observer cannot have failed to notice; it is what is termed the "winged globe," and consists of a small ball or globe, imme-

diately at the sides of which are two asps, and from which extend two wings, each wing being in length about five to eight times that of the diameter of the ball (Fig. 2). The drawing of this device is very grand. The force with which the wings are

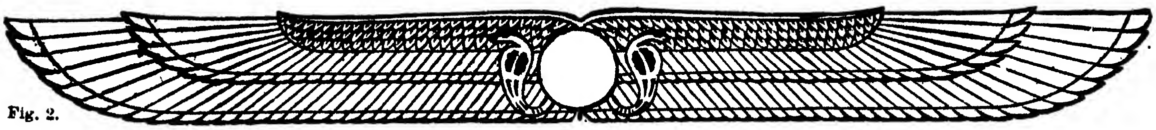


Fig. 2.

delineated well represents the powerful character of the protection which the kingdom of Egypt afforded, and which was symbolised by the extended and overshadowing pinions.

I know of few instances in which forms of an ornamental character have been combined in a manner either more quaint or more interesting than in the example before us. The composition presents a charm which few ornaments do, and is worthy of careful consideration. But this ornament derives a very special and unusual interest when we consider its purpose, the blow which was once aimed at it, and the shock which its perpetuators must have received, upon finding it powerless to act as they had taught, if not believed, it would.

The priesthood instructed the people that this was the symbol of protection, and that it so effectually appealed to the preserving spirits that no evil could enter where it was portrayed. With the view of giving a secure protection to the inmates of Egyptian dwellings, this device, or symbol of protection, was ordered to be placed on the lintel (the post over the door) of every house of the Egyptians, whether residence or temple.

It was to nullify this symbol, and to show the vain character of the Egyptian gods, that Moses was commanded to have the blood of the lamb slain at the passover placed upon the lintel, in the very position of this winged globe. It was also enjoined as a further duty, that the blood be sprinkled on the doorpost; but this was merely a new duty, tending further to show that even in position as well as in nature this winged globe was powerless to secure protection. This device, then, is of special interest, both as a symbolic ornament, and as throwing light on Scripture history.

Besides the two ornamental forms mentioned, *i.e.*, the lotus and the winged globe, we might notice many others also of great interest, but our space will not enable us to do so: further information may, however, be got from the South Kensington Museum library*, where several interesting works on Egyptian ornament may be seen; from the "Grammar of Ornament" by Mr. Owen Jones, the works on Egypt by Sir Gardner Wilkinson; and, especially, by a visit to the Egyptian Court of the Crystal Palace at Sydenham, and by a careful perusal of the hand-book to that court.† Much might also be said respecting Egyptian architecture, but on this we can say little; yet, as the columns of the temples are of a very ornamental character, we may notice that in most cases they are formed of a bundle of papyrus stems bound together by thongs or straps—the heads of the plant forming the capital of the column, and the stems the shaft (Fig. 3). In some cases the lotus was substituted for the papyrus,‡ and in other instances the palm leaf; these modifications can be seen in the Egyptian Court at Sydenham with great advantage, and many varieties of form, resulting from the use of the one plant, as of the papyrus, may also be observed.

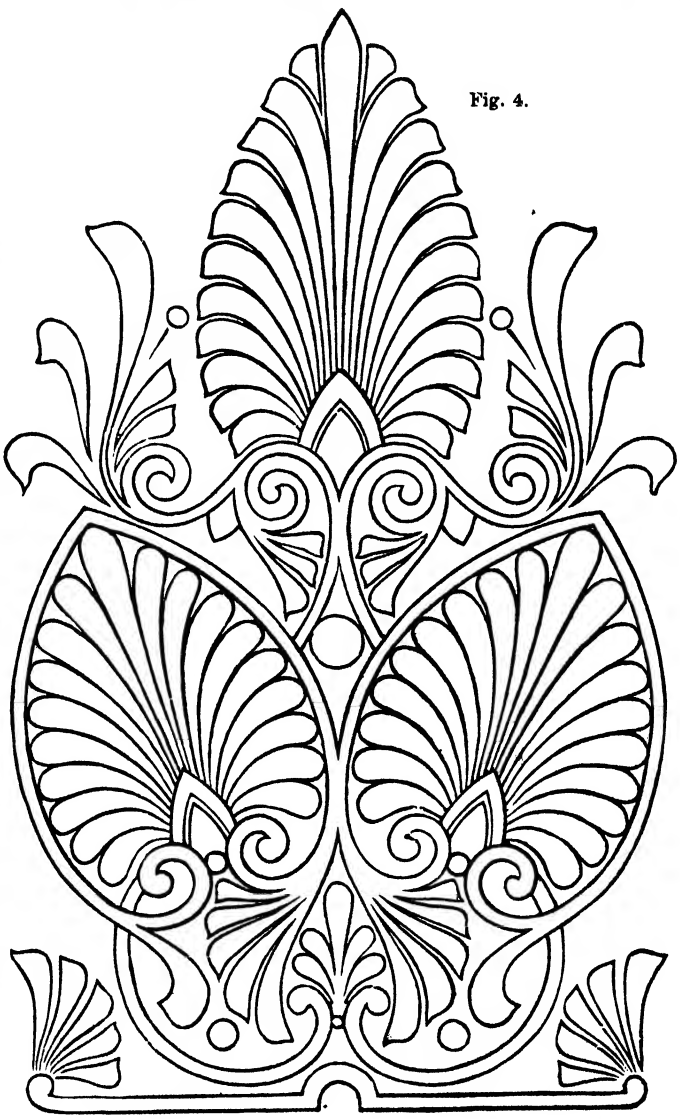


Fig. 4.

We have here an opportunity of noticing how the mode of building, however simple or primitive in character, first employed by a nation may become embodied in its ultimate architecture; for, undoubtedly, the rude houses first erected in Egypt were formed largely of bundles of the papyrus, which were gathered from the river side—for wood was rare in Egypt—and, ultimately, when buildings were formed of stone, an attempt was made at imitating in the new material the form which the old reeds presented. But mark, the imitation was no gross copy of the original work, but a well-considered and perfectly idealised work, having the true architectural qualities of a noble-looking and useful column.

* The South Kensington Museum Art library, its Educational reading-room, etc., are open to any one on paying 6d. a week, 1s. 6d. a month, or 10s. a year.

† A handbook to each of the historic courts erected in the Sydenham Palace was prepared at the time the courts were built. London students cannot do better than make a practice of systematically studying these various courts.

‡ The papyrus was the plant from which Egyptian paper was made. It was also the bulrush of the Scriptures, in which the infant Moses

We must now pass from the ornament of the Egyptians to that of the Greeks, and here we meet with decorative forms having a different object and different aim from those already considered.

Egyptian ornament was symbolical in character. Its individual forms had specific meanings—the purport of each shape being taught by the priests—but we find no such thing as symbolism in Greek decoration. The Greeks were a refined people, who sought not to express their power by their works so much as their refinement. Before the mental eye they always had a perfect ideal, and their most earnest efforts were made at the realisation of the perfections of the mental conception of absolute refinement. In one respect the Greeks resembled the Egyptians, for they rarely created new forms. When once a form became sacred to the Egyptians, it could not be altered; but with the Greeks, while bound by no law, the love of old forms was great; yet the Greeks did not seek simply to reproduce what they had before created, for they laboured hard to improve and refine what they had before done, and even through succeeding centuries they worked at the refinement of simple forms and ornamental compositions, which have become characteristic of them as a people.

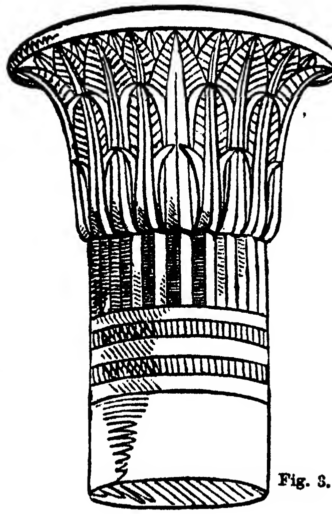


Fig. 3.

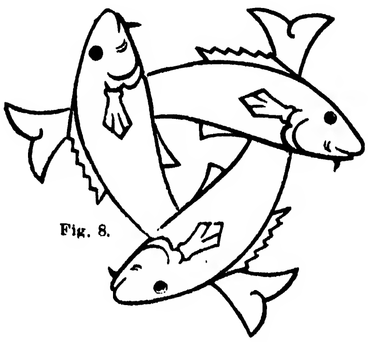


Fig. 8.

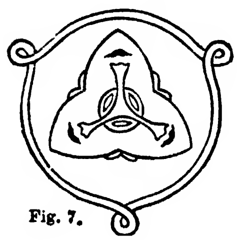


Fig. 7.

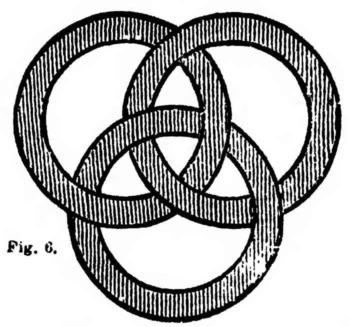


Fig. 6.

The general expression of Greek art is that of refinement, and the manner in which the delicately cultivated taste of some of the Greeks is expressed by their ornaments is perfectly astonishing. One decorative device, which we term the Greek Anthemion, may be regarded as their principal ornament—(the original ornamental composition by one of my pupils, Fig. 4, consists primarily of three anthemions)—and the variety of refined forms in which it appears is most interesting.

But it must not be thought that the Greek ornaments and architectural forms present nothing but refinement made manifest in form, for this is not the case. Great as is the refinement of some of these forms, we yet notice that they speak of more than the perfected taste of their producers, for they reveal to us this fact—that their creators had great knowledge of natural forces and the laws by which natural forces are governed. This becomes apparent in a marked degree when we inquire into the manner in which they arranged the proportion of the various parts of their works to the whole, and especially by a consideration of the subtle nature of the curves which they employed both in architectural members and in decorative forms; but into this matter we must not enter. Yet, by way of throwing some faint light upon the manner in which knowledge is embodied in Greek forms, I may refer to the Doric column, such as was employed in the Parthenon at Athens* (Fig. 5). The idea presented by this column is that of an energetic upward growth which has come in contact with some super-imposed mass, the weight of which presses upon the column from above, while the energy of the upward growth of the column causes it to appear fully equal to the task of supporting the superincumbent structure. Mark this—that by pressure from above, or weight, the shaft of the column is distended, or bent out, about one-third of the distance from its base to its apex (just where this distension would occur, were the column formed of a slightly plastic material), and yet this distension of the shaft is not such as to give any idea of weakness, for the column appears to rise with the energy of such vigorous life, as to be more than able to bear the weight which it has to sustain.

Fig 5.

Mark also the singularly delicate curve of the capital of the column, which appears as a slightly plastic cushion intervening between the shaft and the superincumbent mass which it has to support. The delicacy and refinement of form presented by this capital are perhaps greater than that of any other with which we are acquainted.

The same principle of life and energy coming in contact with resistance or pressure from above is constantly met with in the enrichments of Greek cornices and mouldings; but having called attention to the fact, I must leave the student to observe and think upon these interesting facts for himself. Let me, however, say that there are few classic buildings in England which will aid the learner in his researches; there is now but little poetry in architectural buildings, and but little refinement in the forms of the parts; and, added to this, Greek art without Greek colouring is dead, being almost as the marble statue to the living form. For the purposes of my readers, the Greek Court at the Crystal Palace will be the best example for study.

I might now review Roman ornament, and show that in the hour of pride the materials of which the works were formed were considered, rather than the shapes which they assumed; and how we thus get little worthy of praise from the all-conquering Romans—how the sunny climate and religious superstitions of the East called forth the gorgeous and beautiful developments of art which have existed, or still exist, with the Persians, Indians, Turks, Moors, Chinese, and Japanese; but

* A capital and portion of the shaft of one of these columns are to be seen in the British Museum Sculpture-room, and a cast of the same at the Crystal Palace, Sydenham. This Doric column is employed in the Greek Court of the Crystal Palace.

I have not space to do so; yet all the forms of ornament which these peoples have created are worthy of the most careful and exhaustive consideration, as they present art-qualities of the highest kind. I know of no ornament more intricately beautiful and mingled than the Persian—no geometrical strapwork, or systems of interlacing lines, so rich as those of the Moors (the Alhambraic)—no fabrics so gorgeous as those of India—none so quaintly harmonious as those of China; and Japan can supply the world with the most beautiful domestic articles that we can anywhere procure.

We must pass on, however, to what we may term Christian art, or that development of ornament which had its rise with the Christian religion, and has associated itself in a special manner with Christianity.

Neither the Egyptians nor early Greeks appear to have used the arch structurally in their buildings; the Romans, however, had the round arch as a primary element in the construction of their edifices. This round arch was also used by the Byzantines, and amongst their ornaments we find those combinations of circles and parts of circles, which we find so constantly recurring in later times in Gothic architecture and Gothic ornament. Norman buildings, again, show us the round arch, and present us with such intersected arcs as would naturally suggest the pointed arch of later times, with which came the full development of Gothic or Christian architecture and ornamentation. There was a very fine and marvellously clever development of decorative art, enthusiastically worked at by the Christian monks of the seventh and eighth centuries, called Celtic, of which we have many very beautiful examples in Professor Westwood's great work on early illuminated manuscripts; but what is generally understood by Christian or Gothic art had its finest development about the thirteenth century.

Gothic ornament, like the Egyptian, is essentially symbolic. Its forms have in many instances specific significance. Thus the common equilateral triangle is in some cases used to symbolise the Holy Trinity; so are the two entwined triangles. But there are many other symbols employed in Gothic ornament which set forth the mystery of the Unity of the Trinity. Thus in Fig. 6 we have three interlaced circles, which beautifully express the eternal Unity of the Trinity, for the circle alone symbolises eternity, being without beginning and without end, and the three parts point to the Three Persons of the Godhead. A very curious and clever symbol of the Trinity is portrayed in Fig. 7, where three faces are so combined as to form an ornamental figure.

Baptism under the immediate sanction of the Divine Trinity was represented by three fishes placed together in the manner of a triangle (Fig. 8); but so numerous were Christian symbols after the ninth century, that to enumerate them merely would occupy much space. Every trefoil symbolised the Holy Trinity, every quatrefoil the four evangelists, every cross the Crucifixion, or the martyrdom of some saint. And into Gothic ornamentation the chalice, the crown of thorns, the dice, the sop, the hammer and nails, the flagellum, and other symbols of our Lord's passion, have entered. But, besides those, we have more purely architectural forms making gentle utterance: the church spire points heavenwards, and the long lines of the clustered columns direct the thoughts upwards to heaven and to God.

Gothic ornament, having passed from its purity towards undue elaboration, began to lose its hold on the people for whom it was created, and the form of religion with which it had long been associated had become old, when the great overthrow of old traditions and usages occurred, commonly called the Reformation. With the reformation of religion came a revival of classic learning, and a general diffusion of knowledge, and thus the immediate necessity for art symbols was passing away, it being especially to an unlettered people that an extended system of symbolism appeals. With this revival of classic learning came the investigation of classic remains—the exploration of Greek and Roman ruins; and while this was going on, a dislike to whatever had been associated with the old form of religion had sprung up, which dislike turned to hate as the struggle advanced, till the feeling against Gothic architecture and ornament became so strong, that anything was preferred to it. Now arose Renaissance architecture and ornament (revival work), which was based on the Roman remains, but was yet remoulded or formed anew; so that the ornament of the Renaissance is not Roman ornament, but a new decorative scheme, somewhat of the same genus as that of the Roman. Here, however, all my sympathies end. I confess that all Renaissance ornament, whether developed under the soft sky of Italy (Italian ornament), in more northerly France (French Renaissance), or on our own soil (Elizabethan, or English Renaissance), fails to awaken any feeling of sympathy in my breast; and that it, on the contrary, chills and repels me. I enjoy the power and vigour of Egyptian ornament, the refinement of the Greek, the gorgeousness of the Alhambraic, the richness of the Persian and Indian, the simple honesty and boldness of the Gothic; but with the coarse Assyrian, the haughty Roman, and the cold Renaissance, I have no kindred feeling, no sympathy. They strike notes which have no chords in my nature: hence from them I instinctively fly. I must be pardoned for this sentiment by those who differ from me in judgment, but my continued studies of these styles only separate me further from them in feeling.

It will be said that in my writings I mingle together ornament and architecture, and that my sphere is ornament, and not building. I cannot separate the two. The material at command, the religion of the people, and the climate, have, to a great extent, determined the character of the architecture of all ages and nations; but they have, to the same extent, determined the nature of the ornamentation of the edifices raised. Ornament always has arisen out of architecture, or been a mere reflex of the art-principles of the building decorated. We cannot rightly consider ornament without architecture; but I will promise to take no further notice of architecture than is absolutely necessary to the proper understanding of our subject.

VEGETABLE COMMERCIAL PRODUCTS.—III.

PLANTS YIELDING SPICES AND CONDIMENTS (*continued*).

ALLSPICE, PIMENTO, OR JAMAICA PEPPER (*Eugenia pimento*, De Candolle; natural order, *Myrtaceæ*).—This plant is called *allspice* because it has the combined flavour of all the other spices—that of cinnamon, cloves, and nutmegs entering into its composition. The unripe berries of this plant, dried in the sun, form the allspice. The plant itself is a handsome evergreen, with a straight trunk about thirty feet high, covered with a smooth, grey bark. Its leaves are opposite, short-petioled, elliptical, smooth, and pellucid-dotted, abounding in an essential oil, to which the pimento owes its aromatic properties. The flowers are greenish-white, and the fruit is a smooth, shining, succulent berry, black when ripe, and containing two uniform seeds, the flavour of which resides within the shell.

The allspice is a native of the West Indies, where it is cultivated—particularly in Jamaica, in the hilly parts of the country—in plantations, having broad walks between the trees, called "pimento walks." It begins to bear fruit when three years of age, and arrives at maturity in seven years. Nothing can be more fragrant than the odour of the pimento trees, especially when in bloom; even the leaf emits a fine aromatic odour when bruised.

The berries are collected before they are ripe, at which time the essential oil, to which they owe their pungency, is most abundant. They are spread out, exposed to the sun, and often turned. In about a week they have lost their green colour, and have acquired that reddish-brown tint which renders them marketable; they are then packed in bags and casks for exportation. When dried, the berries are rather larger than a peppercorn. Some plantations kiln-dry them, which expedites the process very considerably.

The consumption of allspice in the United Kingdom is very great, as it is both cheap and useful; but of the quantity imported every year into Great Britain, a considerable proportion is exported. This spice is used as a condiment, and its oil, like that of cloves, is employed as a remedy for toothache.

PEPPER (*Piper nigrum*, L.; natural order, *Piperaceæ*).—This is a climbing vine, with alternate, ovate, acuminate, dark-green leaves, five to seven-nerved beneath, and small inconspicuous flowers, in long, slender, drooping spikes, which are opposite. Its fruit is a round, sessile, one-celled berry, first green, then red, and finally black.

The pepper vine is indigenous to the East Indies, and is extensively cultivated in Sumatra, Java, and on the Malabar coast. A little pepper is also grown in the Mauritius and in the West India islands.

The berries, which resemble those of our holly in size and colour, are gathered as soon as they begin to redden; for if allowed to ripen fully, they lose their pungency. They are dried in the sun, and they become wrinkled and black on the outside. In this state they are known as black pepper, which is the most powerful variety.

White and black pepper are produced by the same plant. This difference in colour is only the result of a difference in the preparation of the berries. To obtain white pepper the berries are allowed to ripen, then dried and soaked in water, and the softened black outer coat is removed by rubbing. The internal seed is of a whitish-grey colour, and, when dried, forms white pepper.

Pepper is a warm carminative stimulant, which is added to food principally for the object of correcting the flatulent and griping character of certain articles of diet—peas and beans, for instance. Both varieties of black and white pepper are sometimes used whole in soups and pickles, but they are mostly ground in a mill, and sold in the form of a powder.

The quantity of pepper annually imported into the United Kingdom is immense. About 6,523 tons of the dried unripe black berries and white ripened seeds of the pepper plant reached this country from the East Indies in 1866. Now, however, this great quantity has almost doubled; for in 1886 there were imported not less than 12,591 tons.

The pepper vine is strictly tropical, but it will grow freely from cuttings wherever the soil and climate are suitable. It is allowed to climb props from ten to thirteen feet in height. These props root freely, the tree from which they are cut being selected with that object in view. The props thus afford both shade and support to the plants. Great care is necessary in the management of the vine, especially in training and tying it to the props. An acre of pepper vines affords an average annual yield of 1,161 lb. of clean pepper.

LONG PEPPER (*Piper longum*, L.; natural order, *Piperaceæ*).—This species, which is wholly different from the black pepper, is found wild in India, and is cultivated in Bengal. The long pepper consists of the fruit catkins of the plant dried in the sun. Long pepper is expensive, and therefore not much used either as a condiment or a medicine.

CAYENNE PEPPER (*Capsicum annuum*, L.; natural order, *Solanaceæ*).—Cayenne or red pepper is not the produce of a pepper plant, but of one belonging to a totally different natural order. It is prepared from the large, red, inflated, pod-like berries of the capsicum, dried and reduced to powder.

The capsicum is a native of the East and West Indies, but cultivated in England, where it can be grown with a very little care. There are numerous species of capsicum, named after the form and colour of the pod, which varies considerably. All are, however, included under the general Mexican name of "chillies."

In tropical countries chillies are used in great quantities, the consumption as a condiment being almost universal, and nearly equal to that of salt. In India they are the principal ingredients in all curries, and form the only seasoning which the millions of the poor of that country can obtain to eat with their insipid rice. The natives of the tropics can eat and relish them raw, which cannot be done by strangers from temperate climates without suffering, the pungent and acrid action of the chillies affecting the mouth and throat.

Capsicums or chillies are imported into this country in the form of red and brown pods, which are broken, dried, and packed in bales, weighing 2½ cwt., principally for making red pepper. Different varieties are cultivated for pickles, and are imported in the pickled state in vinegar from the East Indies. The annual imports from the East and West Indies are from 80 to 100 tons.

Capsicums are useful in cases of putrid sore throat, in malignant scarlet fever as a powerful irritant to be applied in the condition of a saturated infusion externally, so as to draw the internal inflammation to the surface, and thus relieve the throat.

GINGER (*Zingiber officinale*, Roscoe; natural order, *Zingiberaceæ*).—This is an elegant, reed-like, tropical plant, which rises from a creeping rhizome or underground stem. The aërial stem is formed by the cohering bases of the leaves, which are alternate, lanceolate, and sheathing, the nervures diverging from the mid-ribs. The flower-stem springs from the rhizome. The dark-purple flowers are arranged in spikes.

The ginger-plant is a native of the East and West Indies, and is now cultivated generally in hot climates. The ginger of commerce is the dry, wrinkled rhizomes of the plant, which are called "races," and are usually from two to three inches in length, branched, flat, and white in colour. Sometimes the root is dug up when a year old, scalded to prevent germination, and then dried. So prepared, it is called "black ginger," although this term is very erroneous, as the darkest ginger is only a dirty stone colour. Again, the best pieces are selected, the outer skin is scraped off before the ginger is dried, and the pieces, bleached with chloride of lime, constitute what is known in the market as "white ginger." This bleaching process renders the ginger beautifully smooth, but certainly does not improve its quality. Lastly, the *races*, newly formed in spring, are cut off, and boiled in syrup; and the ginger, so treated, is imported in jars under the name of preserved ginger, forming a well-known sweetmeat.

The varieties of ginger recognised in commerce are the Jamaica white ginger, and the Jamaica and Malabar black gingers; also the black varieties, or the Barbadoes, African, and East Indian gingers. Jamaica ginger is considered to be the best. The amount of ginger annually imported into the United Kingdom is about 4,000 tons. The principal use of this spice is as a condiment. Medicinally, it is an excellent stomachic, removing flatulence and griping pains. When used in the form of a poultice, it forms a good rubefacient or counter-irritant.

VANILLA (*Vanilla aromatica*, Swammerdam; natural order, *Orchidaceæ*).—The vanilla is an epiphyte, or air-plant, with a trailing stem, not unlike the common ivy, which attaches itself to trees not as a source of food, like the mistletoe and other parasites, but as a mere point of support, deriving its nourishment entirely from the atmosphere. It grows from eighteen to twenty feet in length. The flowers are greenish-yellow mixed with white, and these are followed by a long slender pod, the fragrance of which is owing to the presence of benzoic acid, crystals of which form upon the pod if left undisturbed. This is, perhaps, the most important genus of the whole orchidaceous family, and the only one which possesses any marked economic value. It grows in the tropical parts of South America, in the Brazils, Peru, on the banks of the Orinoco, and in all places where heat, moisture, and shade prevail.

The pods or fruit of the vanilla are sub-cylindrical, about eight inches long, one-celled, and pulpy within, filled throughout their entire length with very minute black oily seeds, having the appearance of a black paste.

The following is a good account of the method used in preparing vanilla for market—"When about 12,000 of the pods are collected, they are strung like a garland by their lower ends, as near as possible to their foot-stalks; the whole are plunged for an instant into boiling water to blanch them; they are then hung up in the open air, and exposed to the sun for a few hours. Next day they are lightly smeared with oil, by means of a feather or the fingers, and surrounded with oiled cotton to prevent the valves from opening. As they become dry on inverting their upper end, they discharge a viscid liquor from it, and they are pressed several times with oiled fingers to promote its flow. The dry pods lose their appearance, grow brown, wrinkled, and soft, and shrink into one-fourth of their original size. In this state they are touched a second time with oil, but only very sparingly, because, if oiled too much, they would lose a great deal of their delicious perfume. They are then packed for the market in small bundles of 50 to 100 in each, enclosed in lead-foil or light metallic cases."*

As an aromatic, vanilla is much used by confectioners for flavouring ices and custards. The Spaniards employ it extensively in perfuming their chocolate. It is difficult to reduce it to small particles, but it may be sufficiently attenuated by cutting it into little bits, and grinding these along with sugar. The quantity imported into the United Kingdom is very small, but it is in increasing demand.

* See Ure's "Dictionary of Arts and Manufactures," Vol. III., p. 974, 1867.

SEATS OF INDUSTRY.—II.

SHEFFIELD.

BY H. R. FOX BOURNE.

SHEFFIELD, smaller than Birmingham by about a third, is the second hardware town in England. It has an old as well as a modern history. A castle built on a field at the junction of the little river Sheaf with the Don, was the centre of the old lordship of Hallamshire in feudal times, and here Cardinal Wolsey was imprisoned for eighteen days, and Mary Queen of Scots for the best part of fourteen years. Before that, however, the village that had grown up round about began to follow the trade which, till very recently, has been the staple manufacture of the inhabitants. Chaucer speaks of "Sheffield whittles," and from an earlier day the rude knives so known, and other cutlery wares, were chiefly supplied to the Yorkshire districts by Sheffield, while Birmingham carried on a like trade with the midland counties. Neither town could then produce such delicate workmanship as some of the Continental factories. In the reign of Henry VIII. we read of "knives of Almayne, knives of France, and knives of Collogne," but only of whittles from Sheffield. The whittles gradually improved. A case of them was thought dainty enough to serve as a present from the Earl of Shrewsbury, lord of Hallamshire, to Queen Elizabeth. At that time there existed in Sheffield a corporation of cutlers, which in 1624, by charter from James I., became the Cutlers' Company that still has famous influence in the town. But Sheffield was then small and poor. In 1615 it had a population of 2,232, of whom, according to a contemporary record, 100 were "householders which relieve others, and though the best sort, are but poor artificers;" 160 were householders "not able to relieve others, such, though they beg not, as are not able to abide the storm of one fortnight's sickness, but would be thereby driven to beggary;" 1,222 were "children and servants of the said householders, the greatest part of which are such as live on small wages, and are constrained to work even to provide them necessaries;" and the remaining 750 were "all begging poor, not able to live without the charity of their neighbours." The population was 9,625 in 1736; 45,755 in 1801; 185,157 in 1861; 239,916 in 1871; and in 1881, 284,410. During the last two centuries it has nearly doubled in every twenty-five years, and the importance of the town has grown in far greater proportion. Most of the persons now resident in it are concerned, directly or indirectly, in the production of every sort of cutlery, from pen-knives to sword-blades, or of tools, trinkets, cannon-balls, and armour-plates, and the thousand other varieties of hardware manufacture, some of them peculiar to Sheffield, and others in which Sheffield is a formidable rival of Birmingham.

Steel is to Sheffield what brass is to Birmingham. Swedish iron comes into the town in vast supplies by way of Hull, and is skilfully worked up with the help of the coal that is plentiful in the neighbourhood. By far the larger part of the steel made annually in England, which is about equal to the produce of all the rest of the world, comes from Sheffield and its outlying districts, along the shores of the Don, and with this trade is extensively carried on the kindred and older process of cast-iron manufacture. Both cast iron and steel are combinations of pure iron and carbon, the proportion of carbon in cast iron being four or five times as great as in steel. All the efforts of old iron-workers were directed to the removal of every extraneous substance from the ore, so as to render it as ductile and malleable as possible. About 300 years ago it was discovered that the presence of carbon, while rendering iron less fit for ordinary purposes, gave it some special advantages, and accordingly the ore was so treated as that four or five per cent. of carbon should be left in it. The treatment, however, caused manganese and other bodies to be also left in the metal, and the presence of these substances lessens the value of cast iron for all delicate uses. To produce a suitable metal for these uses, therefore, the iron was at first purified as thoroughly as it could be, and then a portion of the carbon extracted from it was restored, the new metal being known as steel.

Most of the various methods adopted for thus manufacturing steel are pursued in Sheffield. In the Cyclops Works of Messrs. Charles Cammell and Co., the most common process, that of cementation, is pursued. The purest malleable iron, generally brought from Sweden or Russia, is broken into short bars, mixed up with powdered charcoal, and subjected to a uniform red heat for ten or eleven days, until a sufficient quantity of carbon is absorbed, and what, from its peculiar appearance, is called blister-steel is produced. Blister-steel is turned into cast steel by another melting and a slight hammering, or into shear steel by hammering alone. Coarser varieties are manufactured by modifications of this treatment, or by subjecting the cast steel to the ordinary puddling process until only the requisite quantity, from one-half to one per cent., of carbon is left in it. All these, however, are costly; and were replaced by a method introduced by Sir H. Bessemer, whereby the crude metal, as it comes from the blast-furnace, was directly converted into steel. The secret of this method is the sudden application of intense heat, under a rapid current of air, to the rough iron, whereby violent boiling and decarbonisation are secured, and tolerably pure steel is turned out with remarkable ease and speed. The process, invented in 1855, has been supplemented by the discoveries of Siemens and others. Not only is the manufacture of steel rendered much cheaper by these improvements, but it can also be produced in larger masses than there were facilities for previously, and thus the metal can be applied to new and valuable uses.

One of these uses, due to Sir Henry Bessemer's fertile invention, is the manufacture of steel cannon-balls. "To facilitate this manufacture," says Mr. Fairbairn, "Mr. Bessemer designed a rolling-mill, now in use at his works in Sheffield, in which lumps of steel are fashioned into spherical balls, from 68 to 300 pounds each in weight, with the greatest rapidity, and with a degree of accuracy never attained in cast-iron shot. The mass to be acted upon is cut from a solid cylinder. The angles of the cylindrical lump are then reduced by pressure between curved surfaces. In this approximate form they are put, at a bright red heat, into the rolling-mill, which consists simply of a revolving table, in which an annular channel is formed. The channel being in section part of a circle of the diameter of the intended shot, a similarly grooved table is fixed above it. The axis of the lower one may be moved end-wise by a hydraulic ram, there being a recess formed in the ram to receive the end of the axis. When a mass of steel is put into this annular channel, and the table set in motion by powerful gearing, the hydraulic ram is made to act on the lower end of the axis, and compress the revolving mass between the grooved surfaces. The lump of steel in its passage round the central shaft also revolves on its own axis, which constantly varies in position, and thus ensures the most perfectly spherical form. To prevent the scale of the metal from roughening its surface, a jet of water passing down the hollow axis is projected against the shot as it revolves, and causes the scale to be thrown off as quickly as it is formed, while a blast of air passing down another passage in the axis blows all these detached scales out of the annular channel. Three balls are best acted upon at one time, so that in three or four minutes this simple apparatus is capable of producing three large spheres, more accurate in size and form than a workman with a slide-lathe could produce in as many days." That "simple apparatus" will serve as a specimen of the numberless methods by which mechanical skill is made to supersede, or rather to economise, hand labour in Sheffield, as in all other manufacturing towns.

A more important illustration of the way in which warlike needs are served in Sheffield, to the great enrichment of the town, is furnished by its manufacture of armour-plates. Iron ships have already virtually superseded the more graceful wooden men-of-war for purposes of naval fighting; but their adoption was long delayed by the peculiar dangers arising from the effects of shot upon ordinary iron steamers. The innovation was opposed by the English Admiralty in 1834 and subsequent years, until 1855, when the Emperor Napoleon caused thick iron plates to be constructed for casing the sides of his iron warships, and their successful use in the Crimean war brought iron-clads into fashion. The Sheffield manufacturers quickly set themselves to supply the new commodity. Messrs. John Brown and Co., who started their huge Atlas Works in 1857, began the enterprise in 1860. They constructed immense rolling-mills adapted for the production of armour-plates, some of them twelve inches thick, nineteen feet long, and four feet wide, and weighing twenty tons. Their example was soon followed by

Messrs. Cammell and Co. at their Cyclops Works, and thus the two largest establishments in Sheffield find a considerable part of their business in providing the munitions of war.

Armour-plates, however, are only special items in the multitudinous productions of these great hardware factories. Other factories have their own specialities; among the most notable being the steel cannon-balls of Messrs. Thomas Firth and Sons, who follow in Bessemer's lead, using their own homogeneous steel in lieu of the Bessemer steel; the saws of Messrs. Spear and Jackson, manufactured at their Ætna Works; and the cast-steel bells of Messrs. Naylor, Vickers, and Co. Making bells weighing 2,000 or more pounds apiece, the last-named firm has proved that steel is for this purpose as serviceable as bronze, and nearly two-thirds cheaper.

These new manufactures have partly ousted knife-making from its old place as the staple trade of Sheffield; but Sheffield is still the great haunt of cutlers, some 1,500 employers having here their workshops, besides about 250 makers of files, while the makers of edged tools number about 150, the saw-makers as many, the makers of hammers about 60, and the engineers' tool-makers about 100. These associated trades provide occupation, for a large part of the community, and in them all the appliances of modern science and art are brought to bear. Each one of the millions of pen-knives manufactured every year in Sheffield, and sent for sale to all quarters of the world, goes through ten or a dozen hands. One man forges the blade; another roughly grinds it; a third softens the metal and affixes the trade-mark of the maker; a fourth hardens and tempers it; a fifth grinds it over again until a fine edge is produced; a sixth fastens it to the handle, which has been prepared by a separate train of workpeople, from wood, horn, ivory, mother-of-pearl, or any of the other substances employed. In file-making and all the other trades of the town there is a like subdivision of labour.

Wire manufacture is another important trade of Sheffield, some wire, for watchmakers' use, being so fine that a hundred miles' length of it would hardly weigh a pound. When steel wire was in fashion for ladies' crinolines, Sheffield produced tons of it in a year.

The trade in which Sheffield competes most directly with Birmingham is that concerned in the manufacture of plated goods. This trade was born in the Yorkshire town. In 1742 one Thomas Bolsover was employed to repair the handle of a knife made partly of silver and partly of copper. It occurred to him that, by placing a thin coat of silver over a thick base of copper, and rolling them together at a high temperature, they might be welded into one mass, and a marketable commodity produced. He experimented successfully, and soon drove a thriving trade in plated snuff-boxes, buttons, and the like. Matthew Boulton adopted the device in Birmingham, and before long both towns were busy with silver-plating and gold-plating. The electro-plating process, begun at Birmingham a century later, was soon copied in Sheffield, and thus each town has helped the other to a new source of wealth. The kindred trade in Britannia metal—an amalgamation of tin, regulus of antimony, copper, and brass—was started in 1770 by two Sheffield workmen named Jessop and Hancock, and now gives employment to one large house and many smaller ones.

Rivalling Birmingham in the general character of its employments, and especially in some of their details, Sheffield differs widely from it in one important respect. The Warwickshire hardware town is a model of freedom from restraint among workpeople, and of harmony between them and their masters. The Yorkshire hardware town, on the other hand, has furnished examples of the evils that result from the antagonism between capital and labour—an antagonism that leads to strikes and trade-outrages. The social condition of the workpeople, who are generally paid highly for the skilled labour of which they are masters, is favourable; and there is now no counterpart to the state of things which, as we have seen, prevailed in the town 270 years ago, when one-third of the inhabitants were "begging poor," and most of the rest were "constrained to work even to provide them necessaries." There are signs of wealth in the cottages as well as in the mansions; but the very prosperity of the labourers has begotten an evil. Jealous of all rivalry, they strive, by every means in their power, to maintain their advantage over the majority of English workpeople. The result is perhaps on the whole regrettable; for a class spirit is thus fostered, and though most of the members as individuals may be free from this spirit, it nevertheless interferes with the healthy development of industry.

APPLIED MECHANICS.—II.

BY SIR ROBERT STAWELL BALL, LL.D., ASTRONOMER-ROYAL FOR IRELAND.

THE PULLEY.

Before commencing this lesson the student should make himself familiar with what has been said on the subject of Pulleys in the lessons on "Mechanics" in the Popular Educator. It will also be necessary to fully understand what is in Lesson XIII. called the "golden rule of Mechanics." This law may be thus stated :—

In any mechanical system the distance through which the power moves multiplied by its magnitude is equal to the distance through which the resistance moves multiplied by its magnitude.

This rule must be thoroughly grasped before any real advance can be made in the practical side of the subject which we now approach. It is often called the "law of virtual velocities," and we shall use this name, though in reality virtual velocities means a general and profound truth in Mechanics, of which the golden rule is only a particular case. We shall also use term *velocity ratio;* this may be defined as the proportion of the distance though which the power moves in a given time to the distance over which the load is moved in the same time. It would follow then, from the principle of virtual velocities, that the mechanical efficiency of a machine is to be expressed by its velocity ratio. This is the usual supposition, and by it various problems in pulleys are solved in Lesson XIV. But when we turn to practice, we find that the mechanical efficiency of a pulley is very much less than its velocity ratio. This is because friction has stepped in and robbed us of our force. No matter how well made be the axles and their bearings, no matter how carefully they be oiled, there is invariably loss of power produced by friction. The student will do well to read the account of friction given in Lesson XVI. It is the presence of this force which imperatively demands that to study the mechanical powers we must first resort to experiment, and then theory will aid us in making our experiments, and afterwards discussing them. We shall find that friction, which at first sight seems embarrassing, and destructive of whatever is symmetrical or elegant in the treatment of the problem, does not really prove so: on the contrary, it leads, when properly studied, to truths of a beauty and profundity beyond any we can attain by theoretical studies of the mechanical powers which do not recognise its presence.

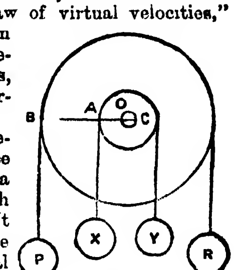


Fig. 1.

EXPERIMENTS ON LARGE AND SMALL PULLEYS.

We shall commence our experiments upon a single pulley, which is merely used for the purpose of changing the direction of a force. This can only be done at a little sacrifice of power, whatever be the size of the pulley; but the loss is greater with a small pulley than a large one. We can study the subject by the apparatus of Fig. 1. This represents an horizontal axle around which the piece A B is capable of turning quite freely. A B is apparently composed of two pulleys fastened together; it is in reality one piece, one of these sheaves being 4·7 times the size of the other. We may place the rope on either the larger groove or the smaller groove, as is shown in Fig. 2. We shall first describe the mode of experimenting with the larger groove, and the same process is to be afterwards carried out with reference to the smaller groove. A rope being placed on the pulley, let a weight, R, be hung at one end. If then an equal weight, P, were placed on the other side, the two would balance. Now, if the

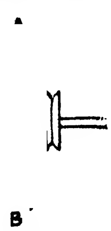


Fig. 2.

had no friction, we should find that the slightest addition made to either of the weights would cause it to descend and raise up the other; but on account of friction, a very appreciable addition must be made to one of the weights before it does this. We shall give the details of one experiment, in which a piece of flexible rope was used, which carried a hook fastened to each end, the hooks having equal weights. A weight of 14 lb. was then placed on each of the hooks. We have now a number of pieces of wire, each of which weighs exactly 0·1 lb. We add one of them to P, but there is still equilibrium, 0·1 lb. not being sufficient to overcome the friction; another and another is added, till we find that when P has received 0·4 lb. it begins slowly to descend; the friction is then conquered, and it is measured by 0·4 lb. Let us now remove the stone weights from the two hooks, and attach to them weights of 56 lb. each. We find that 0·4 lb., which was sufficient to overcome the friction before, is not now enough; 1·2 lb. must be added to the weight P before it descends and raises R. This experiment teaches us that the friction of a pulley about its axle increases with the weights that the pulley is lifting: here the weights are increased fourfold, and the friction has increased threefold. Speaking very roughly, we may often take the friction as proportional to the load raised. This rule gives rather too high a value for large weights, and too low for small weights, but it may be taken as sufficiently correct for ordinary purposes.

Let us remove the rope from the large groove, and place it on the small groove, adding 14 lb. to each of the hooks. The condition of things is so far the same as in the first of the two cases already described, that the two grooves turn as one piece upon the same axle; if, therefore, we find any difference in the amount of friction, it is to be attributed solely to the difference in the size of the two grooves. We load P as before, but we find before it descends we must add to it 3·6 lb.; this, then, is the measure of the friction. It is nine times as large as it was when we used the larger pulley. This difference is not to be attributed to friction only; the rope opposes more resistance to being bent around the small pulley than it does about the large pulley, and this resistance and the friction account for the loss.

It will be easy, by examining Fig. 2, to see that friction must have a greater effect on the small pulley than on the large pulley. The friction is at the circumference of the axle, and always acts to oppose the motion. Supposing P be acting to raise R, P acts at an arm O B, while the friction acts at the arm O C; the leverage of P, therefore, in overcoming the friction is greater than that of X in the proportion of the lengths O A and O B; hence the friction should be 4·7 times larger in the small pulley, that is,

$$4·7 \times 0·4 = 1·88 = 1·9 \text{ lb. approximately.}$$

The difference between this amount and that which was observed,

$$3·6 - 1·9 = 1·7 \text{ lb.},$$

expresses the power that is expended in overcoming the other source of loss, viz., the rigidity of the rope.

The practical conclusion to be derived from these considerations is this: always use pulleys as large as possible. In coal-pits the cage containing trucks of coal is raised to the surface by a wire rope; this generally passes over a large pulley, and from thence to the engine-house. The pulley is large, both for the purpose of avoiding friction, and also to avoid bending the rope too quickly, a process that not only entails loss of power, but also injures the rope. By having a large pulley for the rope to pass over, sudden flexure is not required. The pulleys used in coal-mining are from six or eight feet in diameter up to nearly double this size.

THEORY OF THE PULLEY-BLOCK, INCLUDING FRICTION.

Let n be the virtual velocity of a pulley-block, or, indeed, of any other mechanical power, for the investigation now given applies to all machines.

Let R be the load to be raised, P the power which raises it. If there were no friction, we should have

$$P = \tfrac{1}{n} R;$$

but the presence of friction prevents this equation being true. The power required is always greater than the value given by it.

It is found that the power should be expressed by a formula of this kind—

$$P = A + BR,$$

where A and B are numerical constants whose values must be determined by experiment. The form of this expression should be noticed. Friction is not strictly proportional to the pressure. It is found that the friction is best represented by two terms: one, B R, which bears a certain ratio to the load; the other a constant quantity, A, which is generally small. A also implicitly contains the amount of power necessary to raise the actual weight of the lower block; so that R means only the actual number of pounds attached to the hook. We can easily conceive how A and B can be determined.

Suppose we hang a load, R_1 to the load-hook, and find that a power, P_1, is necessary to raise it, we have, by the formula—

$$= A + BR_1.$$

If now we take another load, R_2, and find the power to raise it be P_2, we have—

$$P_2 = A + BR_2.$$

There are thus two equations between the two unknowns, A and B. From these two equations the values of A and B can be determined by the well-known process which is described in Lessons in Algebra. It will then be found that if any other load, R_3, be raised, the power necessary to lift it will be

$$A + BR_3,$$

thus verifying the formula. Actual values of A and B for one system of pulleys will presently be given. They are found by taking the mean of several different experiments. The principle is essentially the same as here explained, but is a little more accurate. It need not be dwelt on further, as the process is somewhat difficult, and requires considerable calculation.

Let us now deduce from this formula the mechanical efficiency of the machine. This is to be obtained by dividing R by A + B R. We have for quotient—

$$\frac{R}{A + BR} = \frac{1}{B + \frac{A}{R}}.$$

When R is considerable, $\frac{A}{R}$ is very small, and therefore the mechanical efficiency is represented by $\frac{1}{B}$ very nearly.

It will also be useful to ascertain the quantity of energy or work which is usefully employed, and therefore, of course, the quantity which is wasted in overcoming friction. In order to raise R pounds one foot, P must be exerted over n feet, hence n P units of work must be expended to do R units of work; but

$$nP = nA + nBR;$$

and out of this quantity only R is employed, hence the percentage is

$$\frac{100\,R}{n(A + BR)} \quad 100$$

If R be very large, $\frac{A}{R}$ is small, and may be neglected; and we find the per-centage of work utilised to be

$$\frac{100}{nB}.$$

TECHNICAL DRAWING.—VI.

DRAWING FOR CARPENTERS—COFFER-DAMS (*continued*).

FIG. 31 is the section of a much stronger coffer-dam, which is so constructed as to preserve its firmness throughout its entire height. This consists of three rows of piles, *a b c*; the two nearest the water, *a* and *b*, being of the full height of the coffer-dam, and the third, *c*, being half the height. These piles are placed at certain distances apart, and are united at the top and at a point just below the middle by cross-timbers, d^1, d^2, placed horizontally on each side of the piles, and attached by being notched on to the piles; an iron bolt passing through all three timbers. The outer row of piles is connected in a similar manner by the cross-pieces, *c*, which are on a level with the rails, d^1 and d^2. Resting on these, timbers, *f*, are laid across

in pairs—that is, on each side of the piles, so that each pair grasps the piles, and also the strut, *g*, between them; bolts tightened up by means of nuts passing through all three. The transverse pieces at the top of the long piles rest on the longitudinal joists, and are in this example shown notched down upon them, for the purpose already explained in the previous study.

The student must now be reminded that up to this stage the construction is a mere skeleton, the piles being six or eight feet apart. This space is filled in by *sheet*-piling—that is, piles placed in a *sheet* or wall. These are narrower than the true piles, and are driven down between the longitudinal cross-pieces or walls, so as to render the whole construction complete.

This hollow wall is now to be filled in with clay, puddle, etc., and the water having been pumped out of the site enclosed by the coffer-dam, the ground must be dredged, and, if required, a bed of *béton** must be laid down on which to erect the intended pier or other structure.

The following practical hints by Mr. Dobson are quoted for the instruction of the student:—"Leakage between the puddle and the surface of the ground will generally take place unless all the loose, soft, or porous surface-soil be carefully removed by dredging before the puddle is put in. This dredging may be done before or after the piles have been driven. Leakage through the puddle-wall itself may arise from various causes, but may generally be prevented by careful work, and selection of good materials. In the first place, the piles should all be fitted to each other before driving, and should be truly and carefully driven: next, the framing and strutting should be sufficiently strong to prevent any straining or movement under the varying pressure to which the dam may be exposed by alternations in the height of the water; and lastly, the material used for the puddle should be such as will settle down into a solid mass, and should be carefully punned in thin layers so as to secure that no vacuities are left in any part. For this reason it is desirable, when the piles have been driven between the double wallings, to remove the inside walls after the piles are home, as any projections of this kind increase the difficulty of punning the puddle. In order to resist the evil effects which might arise from the swelling of the puddle, the inner and outer rows of piles are usually connected with iron bolts passing through the piles, and secured by nuts, with iron plates and large wooden washers to prevent the former from being drawn into the piles by extreme pressure. These tie-bolts are often found to be very troublesome sources of leakage, as the water soaks in round the bolt-holes, and it is difficult to keep the puddle from settling away from the bolts, and leaving a channel for the passage of water through the dam."

With this information as to the construction of the coffer-dam, the student will not, it is presumed, require any instructions as to copying the example; and he will, as has been already mentioned, do well to draw the various parts in precisely the same order in which they have been mentioned in the description.

WOODEN BRIDGES.

Wooden bridges may be looked upon as the origin of all other constructions for crossing water or roads, whether of stone or iron; for it seems natural to suppose that in the earliest times the simple method of throwing a plank across a stream may have been adopted—in fact, the falling in that position of a tree on the bank would have suggested such an expedient.

A plank placed across from one bank of a stream to the other is, then, the most elementary form of a timber bridge; it is at the same time the most perfect, and the principle on which it is suspended, or kept in its proper position, is worthy of consideration. "For," says Mr. Peter Nicholson, "we may learn how to construct the best and most advantageous kind of bridge suitable for immense spans from this unpretending and apparently unpremeditated contrivance."

When a strong plank is thus laid upon two supports, that part of it which lies midway between them has to sustain its own weight, and that of anything crossing over it, by the cohesion between its particles—that is, by the power with which the atoms or fibres of which it is built up, cling together; for as that part of the plank has nothing to rest upon, it will be clear that it will have a tendency to break somewhere between the supports when the strain upon it exceeds its strength.

But owing to the cohesion of the particles, which attracts them one to another, such a plank cannot snap asunder with absolute suddenness, because the cells of which timber is formed are lengthened out into fibres or hollow threads, and these are so interwoven one with another that one particle or atom of the material will not readily be separated from its fellow as long as such material remains in a sound state. This being the case, the weight upon the beam will cause it to bend, or what is technically termed "to sag,"* and it is to prevent such bending extending beyond a safe amount of elasticity that the efforts of the constructor of wooden bridges are mainly directed.

Absolute construction does not come within the province of these lessons, but, as already stated, the better acquainted a man is with the principles involved in what he is doing, the better will he do his work, and certainly the more interest will he take in it; and therefore, although nothing like a scientific treatise would be in character with the object in view, it is hoped that the following notes on wooden bridges, their history, and peculiarities of construction, may be of interest to those who are now, or who may at any time become, engaged in such works.

It will be easily understood that when a plank is laid across from wall to wall, and a weight is placed on any part of it, it bends, because the particles of which it is formed are pressed close together on the upper side, whilst on the under side they are drawn out. If across a plank so placed you had previously drawn lines exactly corresponding with each other, you would find that when a weight is placed on the plank the lines on the lower will be further apart than those on the upper surface. Thus you will understand that two forces are acting on the beam at the same moment, for the upper portion is subjected to a *compressing* force, whilst a tensile or *stretching* force is acting upon the lower side.

It is the strength with which these two forces counteract each other that constitutes the rigidity of timber, and it will be evident that there must be some intermediate plane between the upper and lower surfaces of the beam in which the two opposite contending forces will meet, in which, of course, neither will preponderate. This is denominated the *neutral plane*, and will be differently situated according to the thickness of the beam, and the power of cohesion which is possessed by the fibres of the various kinds of timber.

In looking back to the early history of wooden bridges, we shall find that where rivers were broad and their channels deep, it would be impossible to cross them by single beams of timber. In such cases a timber framing or scaffolding would be formed in the bed of the river by driving piles, or a pier might be formed of stones or other materials. On these, beams of timber would be placed with one extremity resting upon the pier, and the other on the bank of the river, or on an abutment raised at the water's edge, and upon several piers in the water, as the case might be.

Where the distances between the supports were too great for the dimensions of the timber forming the roadway, the main beams were propped up by struts projecting from the sides of the piers or piles, which were sometimes made to meet in the centre; or if that was not practicable, on account of the distance between the supports, they could each be made to sustain the beam, either by running directly to it from the abutment at about an angle of 45°, or a cross-piece, on which their ends should abut, could be placed between them and fastened to the under side of the beam. These struts or stays were then multiplied and disposed in various ways, until at length a rib or arch of timber was formed to support the roadway, while the spandrels † were filled up with struts and ties to resist compression.

* Kind of concrete, which, owing to its composition, has the property of hardening under water. (See "Lessons on Building Construction.")

* *Sag.*—To yield or give way (Saxon, *sigan*, to fall).

† *Spandrel.*—The irregular triangular space bounded on one side by the curve of the arch, on the second by the vertical, and on the top by the horizontal lines forming the sides of the angular space in which an arch is contained. In architecture this space is often filled with sculptured foliage, figures, &c.

The ribs of bridges constructed in this manner were composed of frames, the lower portion of which form segments of circles, frequently made up of several pieces of wood placed immediately over each other and joggled together, so arranged however, that their ends should break joint. To these circular arcs, or polygonal frames, upright pieces were attached, either by bolts, mortises, or iron straps, by which the weight of beams supporting the roadway was sustained at intervals, and so disposed as that each part might, as far as possible, conduce to the strength of the whole.

The following historical notes as to timber bridges are given in order that the student may glean some intelligence as to what *has been* done—the best possible guidance as to what *may be* done. The extensive use of iron in tubular, girder, and suspension bridges, has in modern times superseded, in a great degree, the use of wood, but not entirely so; and as the principles are applicable to so many other timber constructions, no apology will be necessary for describing some of them, especially as they constitute, both in their complete form and in their details, such excellent studies in drawing for all those engaged in wood-work.

The "Pons Sublicius" was the first bridge ever built across the Tiber. It was at first constructed of timber in the reign of Ancus Martius. *It was put together without either bolts or ties*, so that it could readily be taken asunder, and was built for the purpose of connecting together the Aventine and Janiculum hills.

The bridge over the Danube, by Trajan, is almost one of the oldest timber bridges of which we have a detailed account.

It was supported on *twenty stone piers, which were* 150 *feet high and six feet broad.* On these were framed timber arches each 170 feet span, and formed of three concentric timber rings bound together by radiating pendants. These, together with the arches, supported the longitudinal beams on which the flooring joists were placed across the bridge.

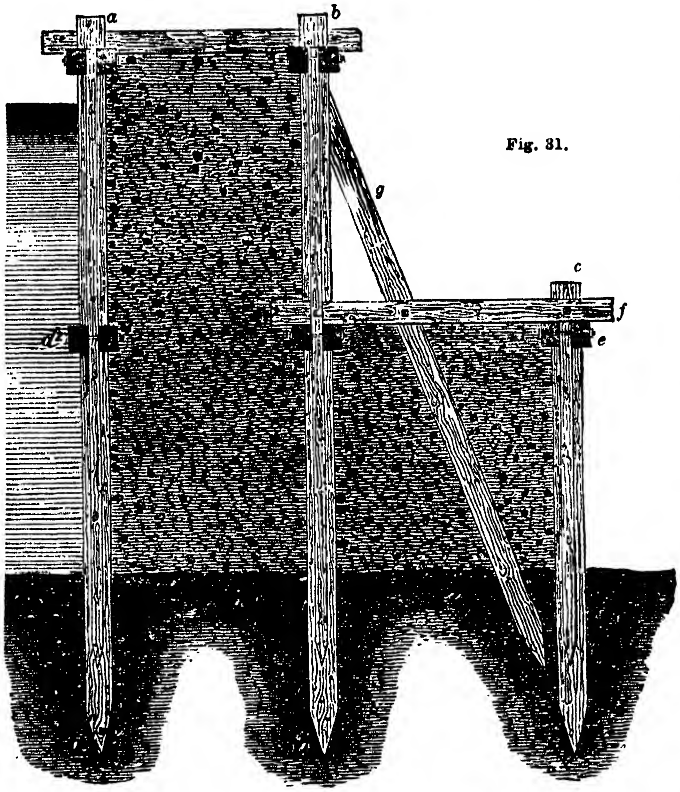


Fig. 31.

The timber bridge of Schaffhausen, built over the Rhine by Ulrick Grubenmann, was remarkable for its ingenious construction. It consisted of two openings, one of 170 feet span, and the other about 190. Its abutments and centre pier were of stone. On these were laid a kind of compound beam formed of three rails or walings, each of which consisted of two longitudinal beams bolted together and toothed into each other so as to be perfectly united; these were supported by an infinity of struts, kept in their places by vertical binding pieces, *all tending to transfer the thrust to the supports* of the bridge. It was roofed in for the ostensible purpose of protecting the timber, but there can be no doubt that the roof added greatly to its strength. This bridge (which was demolished in the year 1800), and others designed by the brothers Grubenmann, were, in fact, timber tubular bridges.

The timber bridge of St. Clair, over the Rhone at Lyons, has seventeen openings, the centre one having a span of forty-five feet, and the others diminishing towards each bank. This bridge has a roadway of about thirty-six feet, which is supported upon piers, each formed of thirteen piles arranged in a single row, running parallel with the banks of the river. On the top of these piles a sill was framed, and longitudinal timbers were made to bear over the head of each pile, and upon these the flooring of the bridge was laid.

The bridge of Grenelle, over the Seine near Paris, built by M. Mallet, consists of two equal and symmetrical bridges, separated by an intermediate piece of dry ground; each of these is formed of three timber bays of eighty-two feet span, *supported upon two abutments and two piers of masonry.* The width of this bridge is nearly thirty-three feet. The ground in the centre measuring eighty-five feet, the whole bridge, reckoning the entire distance from the abutments on either side of the Seine, is 632 feet long. All the foundations were built on piles, upon which a planking was laid.

These foundations were formed by means of coffer-dams, which at low water were not more than five feet deep. A bridge similar to this was built over the Seine at Ivry in 1828.

Besides those, which are merely mentioned as well-known specimens, there is an almost endless number of wooden bridges erected throughout the world, amongst which may be named that at Trenton, in America, of 180 feet span; a bridge over the Tees, 150 feet span; the bridge of Neucetringen, in Bavaria, 102 feet span; that over the Necker, 210 feet span; the bridge of Bamberg, with an opening of 206 feet, erected by M. Wiebeking, an engineer who has constructed an immense number of timber bridges; the bridge of Feldrick, with a span of 65 feet; the bridge of Zeto, built by M. Coffinet, with a span of 125 ft.; besides several put up by the celebrated M. Perronet, a French engineer, who was extremely skilful in forming constructions of this kind.

Before giving some examples for drawing purposes, acting upon my often-repeated wish that my readers should consider drawing as a mental as well as a manual exercise, I ask their attention to the following principles of construction.

Timber bridges are either supported upon piers and abutments of masonry, built on the solid foundation of the ground, or on a platform constructed upon piles driven into the earth, or they are supported upon piers formed upon one or more rows of piles driven in a line with the road or river passing under the bridge. There is almost an infinite variety of ways in which such props or piers may be made. It is, however, usual to drive the piles about a yard apart, from centre to centre, and to bolt capping-pieces or walings to the top of such piles, and either filling up the spaces between with large stones laid dry or else grouted with mortar. On this the masonry for the supports should be placed, or a timber framing, if desired, or else the piles may be carried up to the height of the roadway, being kept in their places by walings and diagonal pieces, bolted on each side of them. These piles should be about a foot square, and when they are driven in salt water or in tidal rivers their surfaces, up to high-water mark, should be sheathed with copper, or otherwise protected from the ravages of the worm.

CONSTRUCTION.—IV.

FOUNDATIONS.

It will be remembered that the term *foundation* refers not only to the surface or bed on which a building stands, but to the manner in which the lower portions of the walls are constructed.

Now, as walls are built either of stones or brick, we think it advisable to give the principles connected with the laying of both these materials before proceeding with the subject of the foundations in which they are to be employed; otherwise several of the terms used might not be understood by the beginner.

MASONRY.—PART I.

Stonemasons class the methods of building walls into (1) *rubble work* and (2) *ashlar work*.

Rubble work is either *uncoursed* or *coursed*.

In *uncoursed rubble* (Fig. 6), stones of any size and shape are used without any reference to their heights. The workman merely uses a tool, called the *scabling hammer*, to chip off any portion which may be unsightly or project from the general surface of the wall; an intelligent mason is, however, careful so to dispose his variously-shaped stones that they may fit into each other, packing in every interstice with smaller stones, filling in every crevice with mortar, and using his plumb-rule to keep his wall perpendicular. It must be borne in mind that the wall is to be composed of stone, which is compact, and mortar, which is yielding; and therefore the more stone, and the less mortar put in, the better. As the mortar will continue to shrink until it is dry and hard, it will be easily understood that a thick bed of soft material will necessarily allow of a greater settlement at the part where it exists than in any other; nor should any stone be placed so as to rest on one part which may project more than another, and be bedded up with mortar, which would, of course, cause unequal settlement when other stones are placed upon it. It will thus be seen that even in the simplest operation there is a scope for intelligent application of thought, and necessity for knowledge of principles.

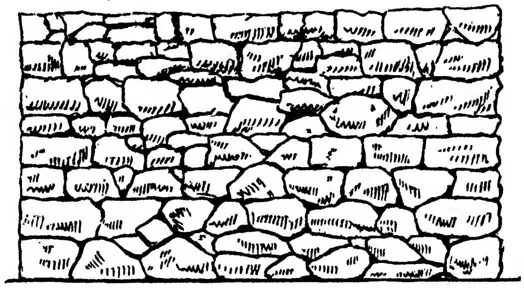


Fig. 6.

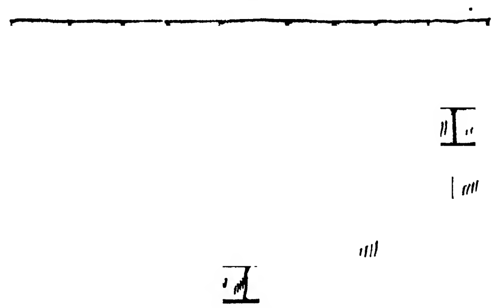


Fig. 7.

Fig. 8.

In *coursed rubble* (Fig. 7), the workman roughly dresses the stones before he begins to lay them. He is careful to get good beds to them, that is, to get the under and upper surfaces of the stones perfectly parallel; he also gets the front of them at right angles to the beds, and tolerably level. The wall is built in courses, which are kept of one height all along in each, although the different courses need not be equally high, nor need the separate stones of which a course may be composed necessarily be equal, but some may be laid on others to make up the height. The stones at the corners are called "quoins," and are always laid with care, as they serve as gauges by which the height of the course is regulated, the workman using the line and level to guide him.

Ashlar work (Fig. 8) is a sort of facing to a wall built either by one of the other methods or of bricks. Ashlar stones, or ashlars, as they are usually called, are neatly squared and tooled on their surface, and are made of various sizes according to convenience or the character of the building. The following is given on the authority of Mr. Peter Nicholson:—

Walls are most commonly built with an ashlar facing, and backed with brick or rubble work. Brick backings are common in London, where bricks are cheaper; and stone backing in the north of England and Scotland, where stone is plentiful. Walls faced with ashlar and backed with brick or uncoursed rubble are liable to become convex on the outside, from the greater number of joints and from the greater quantity of mortar placed in each joint, as the shrinking of the mortar will be in proportion to the quantity; and therefore a wall of this description is much inferior to one of which the facing and backing are of the same kind, and built with equal care, even though both sides were uncoursed rubble, which is the worst of all walling. Where the outside of a wall is of ashlar facing, and the inside coursed rubble, the courses of the backing should be as high as possible, and set in thin beds of mortar. In Scotland, where stone abounds, and where perhaps as good ashlar facings are constructed as any in Great Britain, the backing of the walls most commonly consists of uncoursed rubble, built with very little care.

In the north of England, where the ashlar facings of walls are done with less neatness, they are much more particular in the coursing of their backings. Coursed rubble and backings are favourable to the insertion of bond timbers; but in good masonry wooden bonds should never be in continued lengths, as in case of fire or rot the wood will perish, and the masonry, being reduced by the breadth of the timbers, will be liable to bend at the place where it was inserted. When it is necessary to have wall timber, for the fastening of battens for lath and plaster, the pieces of timber ought to be built with the fibres of the wood perpendicular to the surface of the wall, or otherwise in unconnected short pieces not exceeding nine inches in length.

In an ashlar facing the stones generally run from twenty-eight to thirty inches in length, twelve inches in height, and eight or nine inches in thickness. Although both the upper and lower beds of an ashlar, as well as the vertical joints, should be at right angles to the face of the stone, and the face-bed and vertical joints at right angles to the beds, in an ashlar facing, where the stones run nearly of the same thickness, it is of some advantage in respect of bond that the back of the stone should be inclined to the face, and that all the backs thus inclined should run in the same direction, as this gives a small degree of lap in the setting of the next course; whereas, if the backs were parallel to the fronts, there could be no lap where the stones run of an even length in the thickness of the wall. It is of some advantage, likewise, to select the stones so that a thicker and a thinner one may follow each other alternately. The disposition of the stones in the next superior course should follow the same order as in the inferior course, and every vertical joint should follow as nearly as possible in the middle of the stone below.

By the term *beds of a stone* is meant the upper and lower surfaces of the block. In usual walling these are horizontal;

viz., at the right angle with the face, and are called the lower bed—that is, the one on which the stone rests—and the upper bed, the surface in which the next above it will be placed.

The terms *superior* and *inferior*, when thus used in building, etc., refer to *situation*, not *quality*. Thus the *superior* course means the *higher*, and similarly, *inferior* means the *lower*.

In every course of ashlar facing, with brick or rubble backing, *thorough-stones*, as they are technically termed, should be introduced; their number should be proportioned to the length of the course, and every such stone of a superior course should fall in the middle of two similar stones in the course below. This disposition of bonds should be strictly attended to in long courses.

Thorough-stones or *bond-stones* are stones placed with their greatest length going *through* the thickness of the wall at the right angle to its surface. Some of the ashlar stones must be thus used, or the facing, having nothing to connect it with the backing, would soon separate itself from it and give way. Bond-stones are generally put in alternate courses with backing to the jambs of windows, doors, etc. They are placed alternately in the different courses, so that they may not come immediately over each other, and thus the tying is spread over the whole surface of the wall; but unless the backing be set in quick-setting cement, or otherwise carefully packed, the tendency of the backing to settle away from the facing will not be counteracted.

In every pier where the jambs are coursed with the ashlar in front, every alternate jamb-stone ought to go through the wall with its beds perfectly level. If the jamb-stones are of one entire height, as is frequently the case when architraves are wrought upon them and upon the lintel crowning them, every alternate stone at the ends of the courses of the pier which are to adjoin the architrave jamb ought to be a "thorough-stone;" and if the piers between the apertures be very narrow, no other bond-stone will be necessary in such short courses; but where the piers are wide, the number of bond-stones must be proportioned to the space. Thorough-stones must be particularly attended to in the long courses, below and above the windows.

The term *architrave* is applied to the assemblage of members or mouldings which surround a door or window, the sides of which are called *jambs*, and the cross-top the *lintel* or *traverse*. The under side of the lintel—that is, the *ceiling* of the opening, or the surface seen on looking upward when standing in a doorway—is called the *soffit*.

Bond-stones should have their sides parallel, and of course at right angles to each other, and their horizontal dimensions in the face of the work should never be less than the vertical one. All the vertical joints, after receding about three-quarters of an inch from the face with a close joint, should widen gradually to the back, and thereby form wedge-like hollows for the reception of mortar and packing. The adjoining stones should have their beds and vertical joints filled with oil-putty from the face to about three-quarters of an inch inwards, and the remaining part of the beds with well-prepared mortar.

Putty cement will stand longer than most stones, and will even remain permanent when the stone itself is in a state of dilapidation from the corroding power of the atmosphere.

It is true that in all newly-built walls cemented with oil-putty, the first appearance of the ashlar work is somewhat unsightly, owing to the oil of the putty spreading into the adjoining stones, which makes the joints appear rather dirty and irregular; but if care has been taken to make the colour of the putty suitable to that of the stone, the joints will hardly appear, and the whole work will seem as if one piece. This is the practice in Glasgow, but in London and Edinburgh fine water-putty is principally used.

All ashlars should be laid on their natural beds; that is, *the surface which was horizontal when the stone lay in its native quarry should be placed horizontally in the wall.* To understand this very clearly, the student must be informed that there are two kinds of stone known to geologists, viz., igneous (from the Latin *ignis*, fire), and aqueous (from the Latin *aqua*, water).

The *igneous* are such as have been formed by the agency of fire, which has melted some of their constituent parts and left others hard and bright. The whole of the mass, when hardened, becomes of the same structure throughout, and forms the various sorts of granite used in building.

The *aqueous* are such as have been formed by the numerous rocky particles which have been carried along and deposited by water in past ages. This sediment having become hardened by time and heat, now constitutes most of the stones we use in building, which are sometimes, from their origin, called *sedimentary*.

Now the solid masses we know as stone have not been formed by the sediment which was deposited at one period; but ages may have elapsed between each formation: thus the stone is deposited in layers called strata (from the Latin word *stratum*, strewn or spread out), and this is the reason that such stone may be easily split into slabs, whilst granite would only chip into irregularly-shaped pieces.

This explanation will now enable the student to understand the rule that "all ashlars should be laid on their natural beds," that is, that they should be placed so that the strata of which they are formed should be horizontal, or nearly so, as they were in the quarry from which they were taken. The purpose will be clear to any reflective mind, for it will at once be understood that the strata, when standing on edge, will be more liable to separate as the stone yields to time, the influence of the atmosphere, or to pressure, and thus flakes or layers will separate vertically and drop off, leaving a portion of the stone above unsupported.

The causes of durability of stone, and the correspondent causes of failure and decay, are either chemical or mechanical, and may be described either as decomposition or disintegration. Durability also depends much on the power of resistance to wear. Decomposition is caused by some of the elements of the stone entering into such new combinations with water, gases, or acids, as render them soluble either by air or water. Thus granite, though the hardest of building stones, is liable to serious decomposition when the feldspars are alkaline, and will unite with water or acids. Some qualities of this stone are rapidly decomposed by the sea, and various causes of a similar character affect other stones, the consideration of which would carry us beyond our present subject.

Disintegration is the separation of parts of the stone by mechanical action. One of the chief causes is the freezing of minute drops of water which get into the pores or fissures of the stone, swell slowly as crystals of ice are gradually formed, and consequently burst open the pores or split the grain of the stone; and thus, as said before, if the stones be face-bedded, the laminæ, or thin leaves of which the aqueous or stratified rocks are composed, scale off one after another, just as leaves of a book turn over when it is placed on its back.

Resistance to wear is another obvious cause of durability; but this depends rather on the toughness than the mere hardness of the material (a quality often attended with brittleness), as also on its situation. The crushing weight of Portland stone is about 10,000, while that of York is about 12,000, or one-fifth more; but in many situations Portland steps will last much longer than York. Again, the crushing weight of Peterhead granite is about 18,000, or not quite double that of Portland, whereas, if used as street-paving, it would outlast six sets of the latter.

As many of the principles of building in stone apply equally to brickwork, they will be found under that head, and masonry will be further considered in a section devoted to drawing as applied to stonework.

NOTABLE INVENTIONS AND INVENTORS.

III.—GAS-LIGHTING.

THAT the existence and inflammability of coal-gas should have been known in Europe more than a century and a half before its application to economic purposes is a striking instance in the history of great discoveries. So it was, however—the earliest knowledge of the properties of coal-gas dating from the middle of the seventeenth century, and actual experiments with the gas having been made towards the close of the same century. The Chinese, indeed—pioneers in this as in other discoveries and inventions—are stated to have employed, for ages, spontaneous jets of gas, derived from boring into coal-beds, for illumination and other economical purposes. This inflammable gas is described as having been forced up in jets, and after being conveyed through tubes, was used for lighting streets, apartments, and kitchens; it was used also in

the form of "portable gas" in bamboo canes; and in the village of Fredonia, in the United States, such gas has very long been used both for cooking and illumination.

In England the application dates from the year 1659, when Thomas Shirley correctly attributed the exhalations from the burning well of Wigan, in Lancashire, to the coal-beds which lie under that part of the county; and soon after, the Rev. Dr. John Clayton, influenced by the reasoning of Shirley, actually made coal-gas, and described the results of his labours to the Hon. Robert Boyle, the eminent chemist, who died in 1691. He says he distilled coal in a close vessel and obtained abundance of gas, which he collected in bladders, and afterwards burnt for the amusement of his friends, the gas coming from the bladder through holes made in it with a pin. This was a hint which, in an age more alive to economise improvement, might have brought gas-lighting into operation a century earlier, though the mechanical difficulties might have been too great to be overcome at that period. In 1753 Sir James Lowther described to the Royal Society a spontaneous evolution of gas at a colliery near Whitehaven. It annoyed the workmen so much, that a tube was made to carry it off, and persons were in the habit of filling bladders with the gas and burning it at their convenience. It appears still more strange that this hint did not bring gas into use earlier. A tube was made to carry it off, and it burnt two years and nine months without sign of decrease; it probably diminished as the coal-bed was exhausted.

This discovery was not published in the "Philosophical Transactions" till 1739. Hughes, in his "Treatise on Gas Works," 1853, says, "To the celebrated Dr. Watson, Bishop of Llandaff, we are indebted for the first notice of the important fact, that coal-gas retains its inflammability after passing through water, into which it was allowed to descend through curved tubes;" but there is evidence in the "Miscellanea Curiosa," 1705, vol. iii., p. 201, to show that Dr. Clayton also discovered that gas retains its inflammability after passing through water.

Soon after this, Dr. Watson made many experiments on coal-gas: he distilled the coal, passed the gas through water, and conveyed it through pipes from one place to another, yet it was not introduced into general use; for although the properties of coal-gas were known to so many persons, no one thought of applying it to a useful object, until Mr. Murdoch, the engineer, at Cornwall, in 1792, erected a small gas-holder and apparatus, which produced gas enough to light his own house and offices, and he subsequently erected a similar apparatus in Ayrshire. In the following year he put up works for lighting the Soho Foundry, at Birmingham, with apparatus for the purification of the gas; this light was exhibited complete at the Soho manufactory at the Peace rejoicings in 1802; and upon a similar occasion in 1814 gas was employed to light the pagoda and bridge across the canal in St. James's Park. In 1806 Mr. Clegg exhibited gas lights in front of his manufactory at Birmingham. Halifax and other towns followed. A single mill at Manchester used above 900 burners and several miles of pipe-supply, for the erection of which, in 1808, Mr. Murdoch received the Gold Medal of the Royal Society.

With respect to the tardy progress of gas-lighting, it must not be forgotten that many interesting facts have been adduced to show that the tracks of purely scientific research, and of the subsequent applications to art, have lain very much with different parties. It was not, for example, the chemist who first showed a jet of coal-gas burning in his laboratory, who also first conceived and accomplished the noble feat of lighting up with gas a whole city, so as to make night there almost as light as day.

From the lighting of the Soho Foundry, in 1802, to the close of 1822, Sir William Congreve reported the capital invested in the gas works of the metropolis alone to be one million sterling, while the pipes extended upwards of 150 miles. Still, the light of gas was poor and its smell offensive. Lectures and experiments were next made by a German, named Winsor, who, in 1803-4, lighted the old Lyceum Theatre in the Strand; in the latter year he patented his method, and established a company which subscribed £50,000, expended in experiments, among which was the important process of purifying gas by lime. In 1807 Winsor lighted up the space between Pall Mall and St. James's Park. Two years later he applied to Parliament for a charter, when the testimony of Accum, the chemist, was bitterly ridiculed by the Parliamentary Committee. In 1814 Westminster Bridge was lighted with gas, and on Christmas Day, 1814, commenced the general gas-lighting of London. On Lord Mayor's Day, in the next year, Guildhall was, for the first time, lighted with gas.

In 1814 an explosion occurred at the gas works just established at Westminster, upon which a committee of the Royal Society reported that gas works ought to be placed at a considerable distance from all buildings; and that the reservoirs or gas-holders should be small, and separated from each other by mounds of earth or strong parting-walls. Dr. Arnott significantly records that "such scientific men as Davy, Wollaston, and Watt, at first gave an opinion that coal-gas could never be safely applied to the purposes of street-lighting." Sir Humphry Davy, then President of the Royal Society, asked one of the inventors if it were intended to take the dome of St. Paul's for a gas-holder. (The interior was experimentally lighted with gas in 1822.) In 1825 a Government committee of scientific men reported that their occasional inspection of gas works was necessary, the frightful consequences of leakage and explosion being anticipated.

The following is a brief and general description of the process of the production and purification of coal-gas, the operation being merely a process of distillation. The apparatus consists of (1) the retorts, cylinders of iron or clay, into which the coal being quickly shovelled and the mouth closed by a lid, they are placed on the fire and heated to redness which decomposes the coal and drives forth the resulting gas; (2) the dip-pipes and condensing main, employed to conduct the gas into vessels where the tar and other gross products are removed from it; (3) the purifying apparatus for abstracting the sulphuretted hydrogen, carbonic acid, etc.; and, lastly, the gasometer with its tank, into which the gas is finally received in a purified state. This is effected by the vapours from the coal being carried away by a wide tube, which passes from the cylinder into a series of vessels, where the mixed product is cooled and loses much condensible matter. Thus partially purified, the gas still retains sulphureous and other vapours, to remove which it is subjected, in some gas works, to dilute sulphuric acid, which separates the ammonia; but it is mainly purified by passing it through a series of vessels containing quick-lime, which absorbs the remaining impurities, especially the last traces of sulphur, the presence of which, more than any other circumstance, has prevented the adoption of gas-lighting in private dwellings. Dr. Letheby says of this discovery:—"It is needless to dwell on the importance of this discovery; for it is admitted on all sides that the presence of sulphur, in an unabsorbable form, is one of the most serious objections to the employment of gas as an illuminating agent; and if, as in the present case, the sulphur can be entirely removed, without in the least degree injuring the illuminating power of the gas, it is manifest that *a new era is commenced in the history of gas illumination.* I have no hesitation in saying, from my investigations of the matter, that *this discovery* of the perfect action of lime as a purifying agent *is one of the most important of the present day*, and cannot fail to give an impetus to the manufacture of gas, by securing to the public a complete protection against the hitherto objectionable properties of it."

Here we may note, that a few years ago the refuse from coal-gas works was perfectly useless, but valuable uses have been discovered for gas liquor. From coal-tar are now obtained not only naphtha, benzole, and carbolic acid, but various brilliant dyes and colours.

Under the water-tank, in which the gasometer floats, the gas is introduced, whence it is driven by the weight of the gasometer through cast-iron mains under the streets, and from them, by wrought-iron service pipes, to the burners, the supply being regulated by gauges and valves. Professor Frankland has lucidly explained, at the Royal Institution, the apparatus and processes used in the manufacture, purification, and distribution of coal-gas, by miniature gas works in actual operation. From retorts in a small furnace the products of destructive distillation are successively conveyed through stand-pipes, the hydraulic main, the water and tar well, the condenser, the exhauster, the purifiers, the station-meter, and finally the gasometer, with its governor to regulate the pressure upon the purified gas.

Professor Frankland in estimating the real source of light in coal-gas, refers it to ignited hydro-carbon gases and vapours. These gradually lose hydrogen when exposed to heat, and their

carbon particles shrink together, and form compounds of greater complexity, being some of the dense vapours which exist in a gas-flame; and even the soot produced by a gas-flame is not pure, but requires intense and prolonged ignition to free it from hydrogen. A gas-flame is also perfectly transparent, and gives equal light in different positions. In the comparison of light of equal intensity, obtained from different materials, it is found that coal-gas, and especially gas from cannel coal, is the least unhealthy of all ordinary lights, which is contrary to the usual opinion.

The illuminating power of coal-gas has been greatly improved of late years, but the inquiry is too extensive for our limits. We must be content to mention the passing of gas over naphthaline, when it takes up its vapour, thirty grains of which to one foot of gas increases the light seven or eight times; with oil the result exceeds from four to five times, but even this is an important gain.

Gas has been made from oil and resin, but both are too costly for street-lighting. Wood and peat are also used, and a village in Ireland has been lighted with gas made from bog-turf. The Bude light was first used for lighting the House of Commons in the year 1812; its flame, acted upon by a current of oxygen, had its brilliancy increased by a current of atmospheric air. Now, however, the electric light has been laid on in the House, and is rapidly superseding gas in places where it is required in large quantities.

It has been calculated that an ordinary candle consumes as much air while burning as a man does in the act of breathing; the same may be said with regard to gas, oil-lamps, etc., bearing a proportion to the amount of light evolved. An ordinary gas-light is said to consume as much oxygen as six persons; thus it is that a gas-lit room becomes so oppressive. During the combustion of oil, tallow, gas, etc., water is produced. In cold weather we see it condensed on the windows of ill-ventilated shops. By the burning of gas in London during twenty-four hours, more water is produced than would supply a ship laden with emigrants on a voyage from London to Adelaide.

Dr. Johnson is said to have had a prevision of lighting streets by gas, when one evening, from the window of his house in Bolt Court, he observed the parish lamp-lighter ascend a ladder to light one of the glimmering oil-lamps; he had scarcely descended the ladder half way when the flame expired; quickly returning, he lifted the cover partially, and thrusting the end of his torch beneath it, the flame was instantly communicated to the wick by the vapour which was still issuing from it. "Ah!" exclaimed the doctor, "one of these days the streets of London will be *lighted by smoke.*"

PROJECTION.—VI.

THE PROJECTION OF CYLINDERS.

A CYLINDER is a solid body of the character of a prism, but its *ends* are *circles.* The axis, or line on which a cylinder might be turned, unites the centres of the ends; and if the ends are at right angles to the axis, the solid is called a *right* cylinder. If the ends are inclined to the axis, so that if the cylinder were placed on one of them it would be slanting instead of upright, it is called an *oblique* cylinder. In the first case the ends would be circles; but in the second, although all the sections at right angles to the axis are circles, the ends being at an angle to it are ellipses. It will be readily understood that all sections passing from one end of a cylinder to the other, *parallel to the axis*, will be parallelograms; and by rolling up a rectangular piece of paper it will be seen that the surface of development of a cylinder is a parallelogram, the height of which is equal to the length of the cylinder, and the breadth to its circumference.

Fig. 79 is the plan and elevation of a cylinder when standing on its base, and it will be evident that then, although the cylinder might be rotated on its axis, that axis would remain at right angles to the horizontal, and parallel to the vertical plane.

Fig. 80 shows the elevation of the cylinder when its axis is at 45° to the horizontal, and parallel to the vertical plane.

To project the plan of this, on A B describe a semicircle which will represent half of the end. Divide this semicircle into any number of equal parts, C D, D E, etc., as in Fig. 77 in the last lesson. From the points C, D, E, etc., draw lines parallel to the axis of the cylinder, which, passing from end to end, will give the same points in both. Draw a line for the axis of the plan parallel to the intersecting line, and perpendiculars from the various points in the elevation. Mark off the lengths, *c* C, etc., on each side of the axis, and through the points thus obtained draw the ellipses forming the plans of the ends. Unite these by lines parallel to the axis, which will complete the plan.

Fig. 81 is the projection of the cylinder when the axis is at 45° to both of the planes of projection. No description of the working is deemed necessary, as it is simply a repetition of Fig. 78 in the last lesson, and will, no doubt, be readily understood.

On referring to Figs. 27, 28, 29, 30, the student will be reminded that if a solid be cut across the parts will, when rotated on a centre, form an "elbow"—that is, they may be joined so as to turn a corner. This principle holds equally good in relation to cylinders.

Fig. 82 is the plan and elevation of a cylinder which it is required to cut so that the parts may be joined to form an angle of 90°. The following rule must be impressed on the minds of students, viz.: Whatever may be the required angle, the section must be made at *half* that angle with the axis. Thus, if a pipe is to follow two walls which meet at an angle of 120°, each part must be cut at 60°; and, therefore, in the present figure, draw the section-line, A B, at 45° (half of 90° required). If now the upper part of the cylinder be rotated on a centre (C), the point B will meet A, and the line B F will become A G. Now divide the plan into any number of equal parts at E, D, etc., and carry up perpendiculars from these points to cut the section-line in d', d', e', e'.

To find the true section, draw A B (Fig. 83), equal to the section-line A B in Fig. 82, and set off on this line all the distances, A e', e' d, etc. Through the points e', d', etc., draw lines at right angles to A B, and set off on them, on each side of the line A B, the distances which the points similarly lettered are from the central line A B in the plan, thus obtaining the points C, c, D, d, E, e. Draw the curve of the ellipse, which forms the true section, through these points.

Fig. 84.—To develop this cylinder, draw a horizontal line and a perpendicular, A. On each side of A set off the six equal spaces into which the two parts of the plan in Fig. 82 are divided, viz., A E, E D, etc., and A e, e d, etc., placing the letters E, D, etc., e, d, etc., in the order in which they follow on each side of A. Erect perpendiculars from each of these points, making B F equal to the height of the original cylinder (Fig. 82). Join F F, and the parallelogram B F F B will be the development of the entire cylinder.

To trace the section-line on this development—that is, *to draw the line in which the material is to be cut so as to form both the parts of the cylinder*—erect perpendiculars from each of the points between B, B, and make them the height of those similarly lettered in the elevation. This is best done by drawing horizontals from the points in the section-line to cut the perpendiculars in the development which are similarly lettered. The points A, e, e, d, d, c, c, d, d, e, e, B, B, will be thus obtained; and through these the curve is to be traced, which will be the development of the line of section; and if a piece of sheet iron, or any other material, were so cut, the parts when rolled and joined will give exactly the same figures, the joint or seam being at the highest point in the one, and at the lowest in the other part.

Fig. 85 is a view of the lower portion projected from the plan, when the diameter, A B, is at an angle instead of being parallel to the vertical plane.

Fig. 86 shows the elevation and half-plan of a cylinder, which, on being cut twice at 45°, may be converted into a "double-elbow."

Having drawn the half-plan (only the half is required, as the points in the other half would be immediately at the back of those here given), project the elevation from it; then divide the semicircle into any number of equal parts, and from these points of division draw perpendiculars. Next draw the section-lines at the required angle (in this case 45°), and at the two extremities of the lower one draw lines at right angles to the elevation of the cylinder; make these lines equal in length to the middle portion of the cylinder, and join them by a line at 45°. Erect perpendiculars at their extremities equal respectively to the corresponding lines in the lower portion of the object. Join these by a horizontal line, and this will complete the elevation.

The development of the piece of metal of which this double-elbow is to be cut must now receive our attention. Produce the base-line of the cylinder, and at any part of it erect a perpendicular (Fig. 87), from which set off on each side the same number of equal parts as that into which the half-plan of the cylinder is divided, and draw perpendiculars from the points. From the top of the original *erect* cylinder draw a horizontal line,

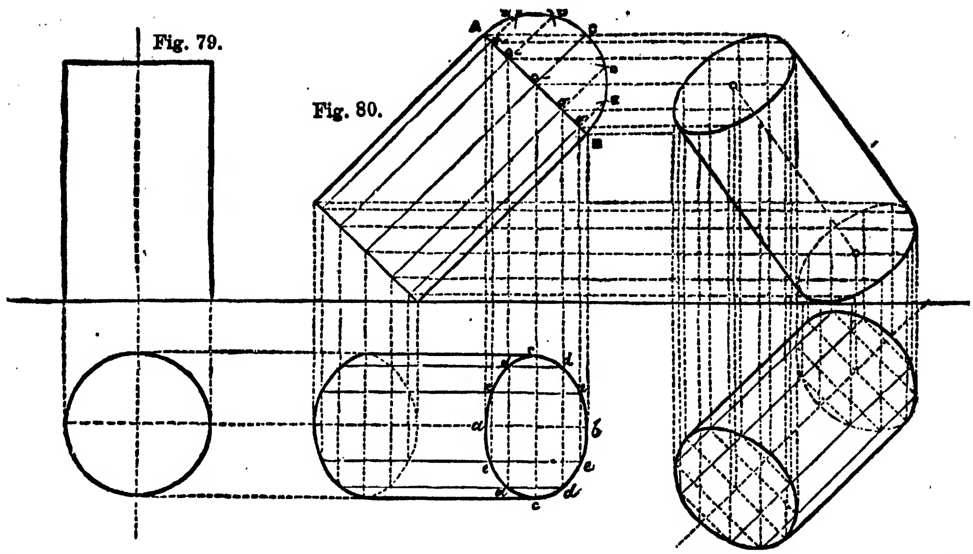


Fig. 79. Fig. 80.

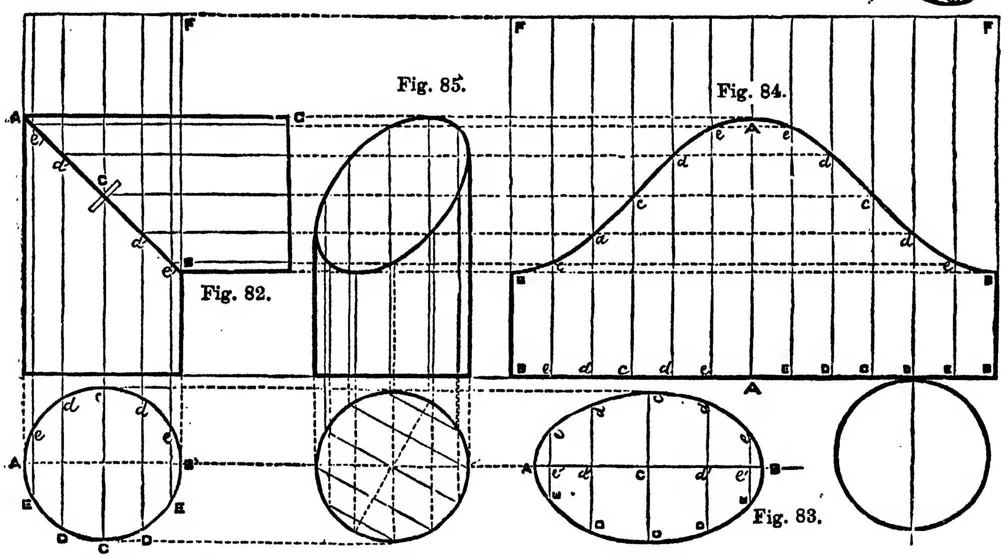


Fig. 82. Fig. 85. Fig. 84. Fig. 83.

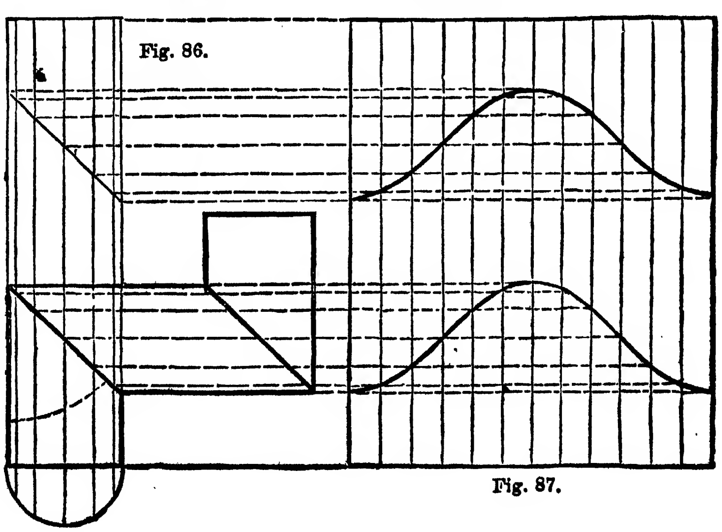


Fig. 86. Fig. 87.

and this, uniting the two external perpendiculars, will complete the general development. Returning now to the elevation of the original cylinder, it will be seen that the perpendiculars which were drawn from the points of division in the plan, cut both of the section - lines, and from these points of intersection draw horizontal lines to cut the perpendiculars in the develop- , that drawn from the highest point (viz., the point where the section-line starts from the side of the elevation) to cut the *central perpendicular*, and that from each of the other points to cut the next *pair* of perpendiculars in succession; through these points the curve, which is the development of the section-line, is to be drawn. The lower section-line will, of course, be developed in precisely the same manner from the corresponding points of intersection oc on it.

Fig. 88 elevation plan of one of the ends of the

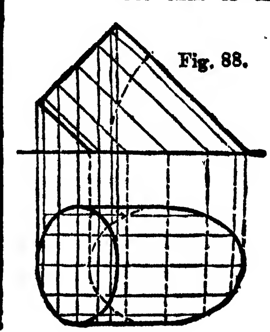


Fig. 88.

above object when resting on its section. On a horizontal line mark off the length of the *section-line in the elevation*, and at the extremities draw lines at 45°; make these equal to the length of the longer and shorter sides of one of the end pieces of the elevation, and join them by a line which will (if their lengths be correct) be at right angles to them. Divide this line into two equal parts, and from the bisecting point draw a line parallel to the sides already drawn; this will be the axis. On each side of this draw lines parallel to it, and at distances apart corresponding with those in the elevation, to meet the intersecting line. Drop perpendiculars from these intersections, passing through a horizontal line drawn in the lower plane; on these set off from the horizontal line the widths of the corresponding lines in the plan; join the extremities by tracing an ellipse to touch each, and this will be the true section on which the object now rests. From each of the points through which the ellipse has been traced draw horizontal lines, and intersect these by perpendiculars drawn from the points occurring in the *end* of the object; through these intersections draw the ellipse, which will be the plan of the end.

ELECTRICAL ENGINEERING.—IV.

BY EDWARD A. O'KEEFFE, B.E., A.S.T.E.,

Demonstrator in Electrical Engineering, City and Guilds of London Technical College, Finsbury.

ATTRACTION AND REPULSION—DIFFERENT KINDS OF ELECTRIFICATION—CONDUCTION AND INSULATION—GOLD-LEAF ELECTROSCOPE—WINTER'S ELECTRICAL MACHINE—ELECTRIC AMALGAM.

It is mentioned by Thales of Miletus (600 B.C.) that when a piece of amber (*elektron*) is rubbed, it acquires the power of attracting light bodies. Dr. Gilbert showed that this property is also possessed in a very marked degree, by such substances as glass, resin, sealing-wax, ebonite, sulphur, guttapercha, etc., and for that reason he called them *electrics;* while those substances, such as the metals, which when rubbed showed no tendency to attract light bodies, he called *non-electrics*. This attraction is due to the fact that the portion of the substance which has been subjected to friction becomes *electrified*, or *charged*, or *excited*, and when any body gets into this state it possesses this peculiar power. The following experiment is instructive:—Take a glass rod quite clean and free from any trace of moisture (it had better be heated), rub it with a piece of silk, and bring it near a light pith-ball which is hung from a stand by means of a thread of unspun silk. The ball will be immediately attracted by the rod, to which it will stick for an instant and then be violently repelled. If a rod of sealing-wax which has been rubbed by flannel be now brought near, the ball will be immediately attracted to it, and after contact for an instant will be once more repelled. The electrified glass rod communicated to the pith-ball by contact a portion of its own charge, and having done so repelled it. When the ball is in this condition the sealing-wax attracts it, clearly showing that its electrification is opposite in kind to that possessed by the glass. If the order of the experiment had been reversed—that is, if the pith-ball had first been brought into contact with the sealing-wax, it then would have received a different kind of electrification, and would have been attracted by the glass rod at the same time that it was being repelled by the sealing-wax. Thus each body attracts the pith-ball when it has been electrified by the other, and each repels it when it has been electrified by itself, while both attract it when in its normal condition. It is evident then, that though both bodies become electrified by rubbing, it is also clear that the electrifications developed on them are distinctly opposite in character, and it is customary to distinguish between them by calling the charge on the glass *vitreous* or *positive* (which may be expressed by the algebraic sign +), and that on the sealing-wax *resinous* or *negative* (expressed by the sign —). *A positively electrified body will attract anything which is either negatively electrified or neutral, and will repel anything which is positively electrified, while a negatively electrified body will attract anything which is either positively electrified or neutral, and will repel anything which is negatively electrified.* This statement is sometimes expressed by saying that like electricities repel, and unlike attract one another.

The kind of electrification developed on those substances known as electrics depends to a great extent on the substance with which they have been rubbed, and the following list is so arranged that any substance will become positively electrified if rubbed by any of those which follow it:—

Cat's Skin.	Flannel.
Glass.	Shellac.
Silk.	Caoutchouc.
The Hand.	Resin.
Sulphur.	Guttapercha.

If any of these substances be rubbed by any following one it will become electrified +, and the rubbing substance will at the same time become charged —. One charge can never be produced alone; if a + charge exists, an exactly equal — one must be produced at the same time.

In the case of all those bodies called by Gilbert electrics, and now known as *insulators* or *non-conductors*, the electrification developed by friction remains at the spot where the friction takes place, and does not spread itself uniformly over the surface of the body. They can communicate their charges to other bodies by means of contact, as in the case of the pith-ball, but a charge can also be communicated by another means; namely, by *conduction*. A simple experiment will best explain this. Suspend (Fig. 1) a pith-ball H_1 by a silk fibre, and from it hang another pith-ball H_2 by a metal wire. Touch H_1 with an electrified glass rod and it will be immediately repelled, and if the rod be now brought near H_2 without touching it, this ball will also be repelled, and will behave in every respect as if it had been in contact with the rod. The positive charge which it has, was conducted to it by the wire from H_1. If, instead of the metal wire a silk thread had connected H_1 and H_2, no charge would have been communicated to H_2, showing that silk does not conduct electricity, or, in other words, is a non-conductor. This power of a substance to conduct electricity is the only difference between an electric and a non-electric; an electric is a non-conductor, a non-electric is a good conductor. No substance conducts electricity perfectly, and no substance altogether insulates or prevents its flow, though many bodies approximate to these extremes, and between them there are many of varying degrees of goodness or badness as conductors. In the following list each substance is a better conductor than any which follows it:—

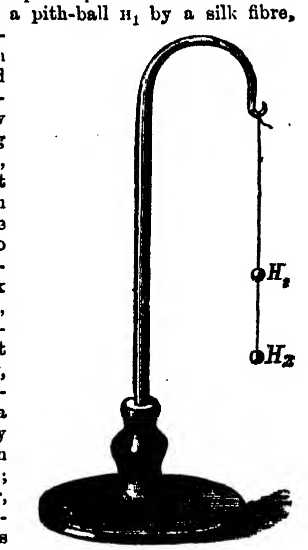


Fig. 1.—ILLUSTRATING CONDUCTION.

GOOD CONDUCTORS.

Metals.	Salt Solutions.	Snow.
Charcoal.	Sea Water.	Growing Vegetables.
Graphite.	Fresh Water.	The Body.
Acids.	Rain Water.	Soluble Salts.

PARTIAL CONDUCTORS.

Linen.	Flower of Sulphur.	Straw.
Cotton.	Dry Wood.	Ice at 0
Alcohol.	Marble.	
Ether.	Paper.	

NON-CONDUCTORS OR INSULATORS.

Oils (fatty).	Leather.	Glass.
Phosphorus.	Parchment.	Wax.
Lime.	Dry Paper.	Sulphur.
Chalk.	Hair.	Resin.
Caoutchouc.	Silk.	Amber.
Oils (ethereal).	Precious Stones.	Shellac.
Porcelain.	Mica.	Dry Air.

Any of these substances will become negatively electrified if

rubbed with cat's fur, but in the case of the conductors the charge gets conducted off through the hand as soon as it is formed, unless some device is adopted to prevent it. If the substance be fixed on the end of a rod of glass, ebonite, or some such non-conductor, and then rubbed, it will become negatively electrified, and the charge will be distributed over its whole surface, the insulating handle preventing any loss by conduction.

The use of the pith-ball for investigating these phenomena was practically discontinued when Abraham Bennet invented what is now known as the *Gold-leaf electroscope*. The instrument here illustrated (Fig. 2) is Professor W. E. Ayrton's modification of Bennet's electroscope, and is undoubtedly the best form of that instrument. It consists of a strong glass shade, G G, mounted on a wooden base; on the inside of this shade is pasted a number of strips of tinfoil, T, the ends of which are in metallic connection with the terminal screw, S. From the wooden base rises a glass rod, *g g*, bent into the form of a gallows, and carrying a short metal tube, *t*, through which it passes, fitting tightly. To this tube is fixed a wire, W, which projects through the ebonite cap on the shade (but without touching it), and terminates in a brass ball, W. To the lower end of this wire is attached a pair of light gold-leaves, L. The glass vessel, V, contains pieces of pumice-stone soaked in strong sulphuric acid which absorbs any moisture and keeps the instrument perfectly dry; *p* is a brass plug, sliding stiffly on the wire W, and fitting tightly into the hole in the ebonite cap when the electroscope is not in use.

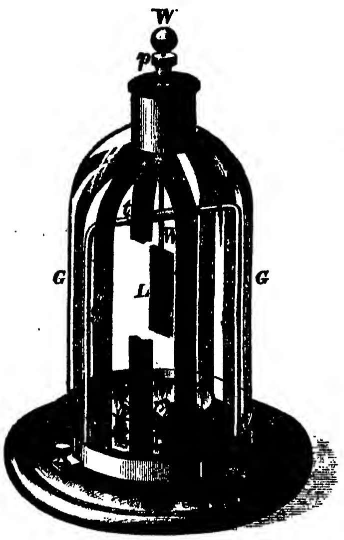


Fig. 2.—GOLD-LEAF ELECTROSCOPE.

In order to use this instrument, the plug *p* is raised as shown, and the charge communicated to the knob W. This charge immediately distributes itself over all the conductors (including the gold-leaves) which are in contact with the knob. The gold-leaves—which till now had been hanging vertically—on being similarly electrified, will instantly fly apart, and will remain so as long as they retain their charge; and as this charge can only leak away along the glass rods *g g*, which are in themselves good insulators, the instrument retains its charge for a considerable time. The tinfoil strips, T, preserve the gold-leaves from the effects of any external influence. It may be remarked that the leaves should be made of pure gold, not of "Dutch" metal, as is sometimes the case.

The rubbing of glass rods is a very simple and convenient way of generating small electrical charges. To obtain these charges on a large scale, some mechanical device must be adopted, where plenty of friction is brought to bear on a large surface. Perhaps the best type of frictional machine is the *plate* form, due to Carl Winter, of Vienna (Fig. 3). This machine consists of a glass or ebonite disc, S, fixed on a spindle G_2, which is rotated by turning the handle K. This disc passes between two rubbing surfaces supported on glass pillars G_1 G_3. The positive charge generated on the surface of the disc by friction is collected by the wooden rings, *r*, which have a number of metallic points almost but not quite touching the glass. This charge is then conducted to the brass ball C, which is supported on the glass pillar G_4. The rubbing surfaces are connected by a wire to the discharging-rod E, which is also supported on a glass pillar. This rod E is not a fixture, but can be brought near O whenever it is desired to get a discharge in the form of a spark. The large wooden ring W contains a spiral of wire, and serves to increase the capacity of the machine; or, in other words, to increase the length of the spark which can be obtained from it. All the metallic or conducting portions of the machine are rounded off at the ends, as the charge is quickly dissipated when allowed to accumulate on points. The rubbing surfaces

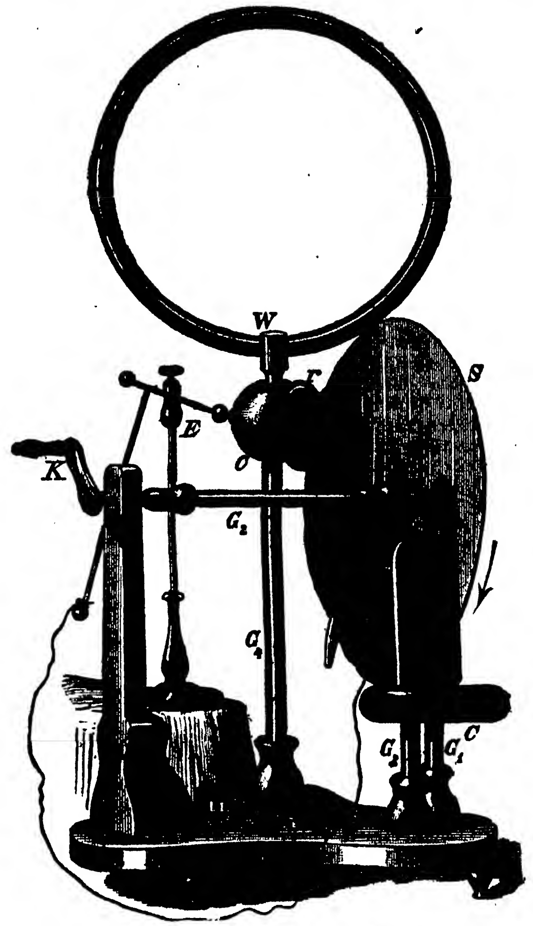


Fig. 3.—WINTER'S ELECTRIC MACHINE.

are covered with leather, which is coated with electric amalgam, a substance which can be made by melting equal quantities of tin and zinc, and then mixing them with twice their weight of mercury. When cold, this compound is quite brittle, and can be ground into a powder, which, when mixed with vaseline and placed on the rubbers, gives them the necessary metallic surface.

FORTIFICATION.—II.

BY AN OFFICER OF THE ROYAL ENGINEERS.

TYPES OF FIELD PROFILES ON LEVEL GROUND—DEFINITIONS—NAMES OF SLOPES, ETC.—USES OF VARIOUS PARTS OF PROFILE—PENETRATION OF RIFLE BULLETS—PENETRATION OF ARTILLERY—NECESSITY FOR VARIETY OF PROFILE TO SUIT THE GROUND—DEFINITION OF DEFILADE—MEANS OF AFFORDING ADDITIONAL SECURITY TO MEN FIRING OVER THE PARAPET.

Types of Field Profiles.—The ordinary earthen parapet is a mound of earth thrown out from an excavation near it.

When this excavation is behind the mound it is called a *trench*, and when it is between the mound and the enemy, it is called a *ditch*.

In the latter case, the defenders either fight on the same level

as their opponents, or are raised above them, and the excavation serves as an obstacle to the enemy's advance.

When (as in permanent fortification) it is possible to make the *ditch* both broad and deep, it forms a serious obstacle, and affords sufficient earth for the formation of a really important parapet (Fig. 1).

In field works, however, it rarely happens that the ditches can be made more than ten or twelve feet deep, in which case the obstacle is not sufficiently formidable, and additional arrangements must be made to delay the enemy under the close fire of the work.

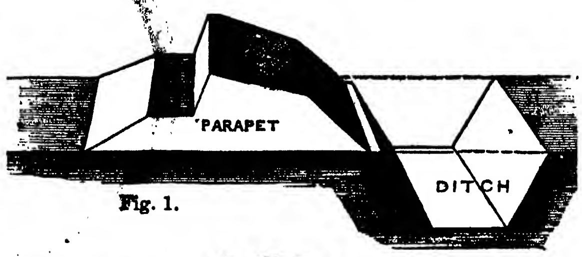


Fig. 1.

When completed with a sufficiently high parapet, this is the best formation, as it offers the advantages of a commanding position to the defenders, and protects them by an obstacle in front; it is not, however, a rapid method of obtaining cover.

Cover is more rapidly obtained by excavating a trench, in which the defenders can stand to fire over the mound of excavated earth; because by this arrangement they are protected by the parapet as well as by the depth of the excavation. Thus, for instance, a trench three feet deep will afford about six feet of cover. The trench formation is therefore generally adopted for hasty entrenchments in the field, and for the parallels and approaches employed in sieges, to enable the besiegers to advance towards the well-armed and formidable works of a fortress (Fig. 2).

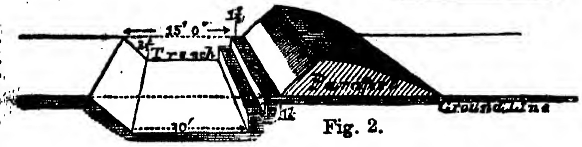


Fig. 2.

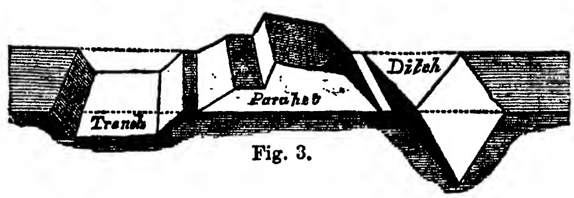


Fig. 3.

It must, however, be observed that there is no obstacle whatsoever opposed to the enemy, and that as the defenders are standing in the trench, they are lower and consequently fighting to a certain extent at a disadvantage with an enemy outside.

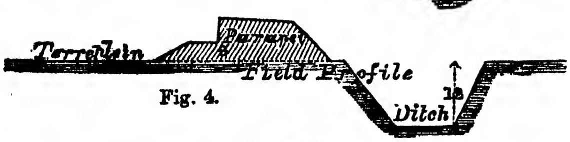


Fig. 4.

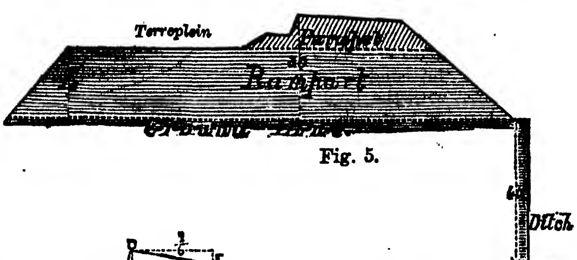


Fig. 5.

Occasionally, when there is plenty of labour available, but when the time for the construction of the parapet is limited, or when it is desirable to construct a thicker parapet in a given time than could have been obtained by either of the above methods, a double set of workmen are employed—one party digging a ditch and the other a trench, and throwing up the earth between them (Fig. 3).

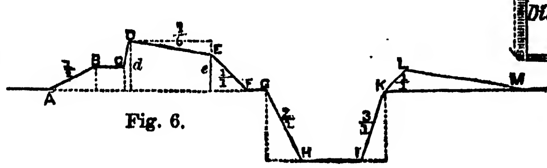


Fig. 6.

This arrangement has many [illegible]es; it has, however, the defect belonging to all trench formations, viz., that the trenches are liable to be flooded in rainy weather, unless special arrangements are made to drain them; and that, unless the parapet is unusually high, the defenders are only under cover while standing in the trench.

It is applicable to rocky or marshy sites, where neither ditch nor trench can be made deep enough to provide sufficient earth for the parapet.

Definitions.—The following terms are frequently made use of with reference to the profiles of works, and should be understood:—

A *revetment* is an arrangement for supporting earth at a steeper slope than it would naturally assume, and various materials may be used for this purpose.

The *command* is the height of the highest point or crest of a work above the level of the ground on which it stands; or above some other work over which it has to fire.

The former is termed the *absolute command*, the latter the *relative command*. A work is said to have a *command of fire* over another work, when its relative command is such as will admit of a direct fire from both parapets being kept up simultaneously, without danger to the defenders of the front work.

Assuming the work to be on level ground, in the same plane with the enemy's position, and that the parapet should be capable of giving cover and protection to men of ordinary stature standing a certain distance in rear, it is evident that the crest must at least be six feet higher than the level on which they stand; and when it is remembered that the trajectory or path of the enemy's projectile is a curved line, it is plain that this height must be exceeded. A command of eight feet gives a fair amount of protection, but a greater command would, of course, be better.

The *relief* is the difference of level between the *crest of the parapet* and the *bottom of the ditch*, or the command + depth of ditch.

The *terreplein* of a work is the level surface within it on which the active operations of the defence—such as working the guns, etc.—are carried on. In field-works with a low command, the terreplein is usually the original ground-line (Fig. 4); but in permanent works, with a command of twenty or thirty feet, the terreplein is the level surface on the top of the embankment or rampart (Fig. 5).

These terms "rampart" and "parapet" are so frequently misapplied, that it would be well to note that the rampart is simply an embankment or mass of some material which raises the parapet to the required level.

Names of Slopes, etc.—The names of the various parts of a profile (Fig. 6) are—A B. Slope of the banquette. B C. Banquette. C D. Interior slope of parapet. D E. Superior slope of parapet. *d e.* Thickness of parapet. E F. Exterior slope of parapet. F G. Berm. G H. Escarp. H I. Bottom of ditch. I K. Counterscarp. K L M. Glacis. K L. Interior slope of glacis. L M. Slope of glacis.

Uses of various parts of Profile.—When the parapet is high enough to give cover to those not actually defending it, a platform or step must be made at a convenient level (usually 4 feet 6 inches) below the crest, to enable the defenders to fire over the top of the parapet, with as little exposure to themselves as possible. This step is called a *banquette*; its breadth is 4½ feet when two ranks of men are to fire, and 3 feet when only one rank is required.

The level of the banquette is gained either by steps or by a slope of about ½, called the *slope of the banquette*, which is a sufficiently easy incline to enable men to go up or down with ease.

To enable the men, when firing, to stand close up to the

parapet, its *interior slope* is made about $\frac{3}{1}$, and as ordinary loose earth will not stand at so steep an angle for any length of time, it is supported by a revetment of sods, or some other material.

The *thickness of parapet* is the horizontal distance between the crest and the exterior slope, or, in other words, it is the base of the superior slope. It is regulated so as to exceed the penetration of the projectiles it is intended to resist.

Penetrations of Rifle Bullets.—These penetrations are very various with different guns at different ranges, and of course vary with the hardness of the resisting medium. The details of the various experiments on this subject would be too numerous to state here, and it will, perhaps, be sufficient to note some of the results. First, with reference to the penetration of small arms, we have the results obtained experimentally from the Martini-Henry, and recorded in the "Proceedings of the Artillery Institution," 1869 :—

Mantlets of four thicknesses of three-inch rope were proof against bullets at 400 yards. A gabion (or cylindrical basket two feet in diameter) filled with clay *was* penetrated at twenty-five yards, but not at longer distances. Two planks of green oak were *not* penetrated at 100 yards. Twelve inches' thickness of fir planking was penetrated at 100 yards.

Earthen parapets, or sand-bags filled with earth, 2 feet or 2 feet 6 inches thick, are proof against any small arms whatever.

Penetration of Artillery.—The penetrating power of artillery has increased enormously in the last few years, and the earthen parapets of field-works, which a few years ago would have been made 6 or 18 feet thick, must now (if time admits of its being done) be increased to 12 or 24 feet thick to resist field artillery ; and in permanent works, to withstand the heaviest artillery, earth parapets from 45 to 50 feet thick will be required.

The top of the parapet is made to slope to the front, to admit of the musketry fire from the work sweeping the ground on the further side of the ditch. This is termed the *superior slope*, and is usually about $\frac{1}{6}$. In an earthen work it should never be made more than $\frac{1}{4}$, as if it were so, the thickness near the crest would be too weak to resist the enemy's projectiles.

The *exterior slope* is the outside portion of the parapet most exposed to fire, and consequently should be built at the inclination that the soil of which it is composed would assume when loosely thrown up.

Made-earth will rarely stand at a steeper angle than 45°, or $\frac{1}{1}$, and in sand or loose soils the angle is less ; it must therefore be understood that, although the exterior slope will be assumed as $\frac{1}{1}$ for purposes of calculation, etc., it would in reality depend on the soil, and probably would be less steep than this.

Berm is a space left between the foot of a slope and the edge of the excavation near it. The berm at the foot of the exterior slope is useful, as it facilitates the repair of the parapet, and tends to prevent the weight of the parapet from breaking down the earthen slope of the escarp, and slipping into the ditch.

The *escarp* is the side of the ditch nearest to the work. In order to make it difficult for the enemy to get up, it would be desirable to make the escarp vertical ; but the weight of the parapet prevents this being possible in field-works with unrevetted ditches. It therefore is a slope varying from $\frac{2}{1}$ to $\frac{1}{1}$, according to the tenacity of the soil.

In permanent works, the escarp is a very formidable obstacle, usually a wall about thirty feet high, placed in the ditch so as to be hidden from the distant view and fire of the enemy, and where it can only be destroyed with great difficulty.

The *ditch* provides the earth for the parapet, and, if deep enough, serves as an obstacle.

Owing to the difficulty of throwing the earth higher than twelve feet, the ditches of field-works rarely exceed that depth. In permanent fortifications, when time and labour are available, the ditches are much deeper—in some cases exceeding 50 feet in depth, as, for instance, at Portland and at Malta.

The width of the ditches in field-works is never very great, but in permanent works it varies from about 50 feet to 60 yards. N.B. The ditches of the works at Antwerp are 60 or 80 metres in width.

The *counterscarp* is the side of the ditch opposite to the *escarp*, and as there is but little weight to bear on it, this slope in field-works may be made as steep as the soil will admit of. In a firm soil, and with moderate level strata, it will stand for some time at a slope of $\frac{3}{1}$; but all steep earthen slopes should be revetted to withstand the effects of rain and frost. In permanent fortifications the counterscarp is usually a wall which, in some cases, has a gallery behind it, and is loopholed to allow of a musketry fire being brought to bear on the bottom of the ditch.

The *glacis* is a mass of earth placed on the outer side of the ditch, to bring the ground beyond the counterscarp under the fire from the parapet ; and is also used in field-works to protect, from the enemy's fire, the various obstacles intended to delay his advance (Fig. 7). The earth necessary for this latter object can be obtained by excavating, as shown above.

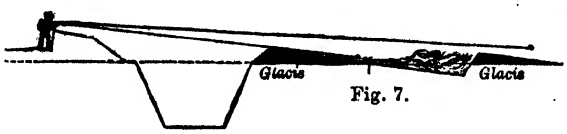


Fig. 7.

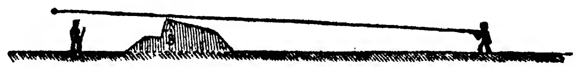


Fig. 8.

Fig. 9.

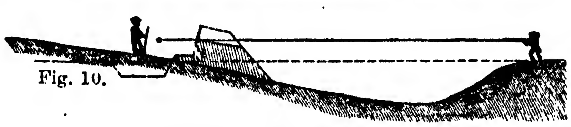


Fig. 10.

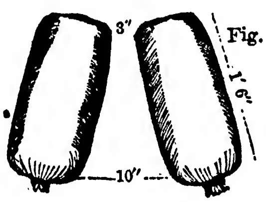


Fig. 11.

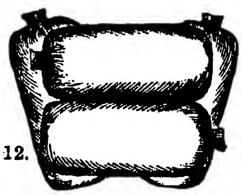


Fig. 12.

Fig. 13.

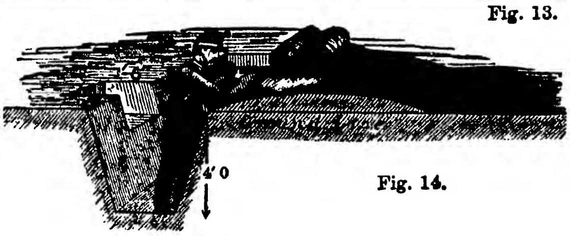


Fig. 14.

In all the foregoing examples it has been assumed that the works were on level ground, and that a parapet eight feet high would protect men standing in rear of it ; and that men, while firing over an earthen parapet, are only protected breast high. Let us now consider how these arrangements must be modified when the ground is sloping, or the enemy is on a higher level than the interior of the work ; and then how better protection can be obtained for the men firing over the parapet.

Necessity for variety of Profile to suit the Ground.—From Figs. 8, 9, 10 it will be seen that, although a height of eight

feet of parapet may be sufficient on level ground to protect men standing behind (Fig. 8), it will be necessary to obtain more cover by either raising the crest or lowering the terreplein when (as in Fig. 9) the enemy is on higher ground, or (as in Fig. 10) when the enemy is on the same level as the work, but the ground rises behind it.

Definition of Defilade.—The various practical operations that are gone through to ascertain how much the parapets should be raised to obtain cover, are called *defilade*, and will be further explained hereafter. To protect the head and shoulders of men firing over the parapet, loopholes are made on the superior slope, by laying two filled sand-bags on the slope, as shown in Fig. 11, and then laying two other filled sand-bags across them, as in Fig. 12. When sand-bags are not available, a stout log of timber may be laid lengthwise along the crest, and supported at intervals, so as to leave room underneath for men to fire between it and the crest (Fig. 13). This gives good bullet-proof cover; but if hit by a shot or splinter of a shell, the beam will probably be carried away, and may kill the men standing behind it. Fig. 14 shows a section of a rifle-pit with sand-bag loophole.

AGRICULTURAL CHEMISTRY.—III.

BY SIR CHARLES A. CAMERON, M.D., PH.D.,
Professor of Hygiene in the Royal College of Surgeons, Ireland, etc.

CHAPTER III.—HOW PLANTS GROW.

THE final act of vegetation is the production of seed, after the performance of which function the individual plants of many species immediately perish, having in the reproduction of similar organisms accomplished their destined career. The seed developed by the mature plant contains the germ of the future individual, which may therefore be regarded as the heir to the plant; and as the provident human parent lays by a store for his offspring, intended to supply their wants until the time arrives when they shall be able to provide for themselves, so also does the parent plant ceaselessly occupy itself during a portion of its existence, in accumulating provisionary stores destined to nourish its offspring during the earlier stages of its growth. This analogy is interesting, and it admits of being further extended.

The first process which takes place when the embryo plant contained in the seed is about to assume an independent existence is termed *germination*. In order to describe this process, we must first explain the structure of the seed. We will take the common garden bean as an example. It consists of an integument, covering, or case, termed the *testa* (Fig. 4), which encloses the embryo, or immature plant. On dissecting the seed, two large oblong and flat bodies are observed, which bear some resemblance to leaves, and are termed *cotyledons*. The bean contains two of these organs, but other kinds of plants have a greater number, whilst a few species are destitute of them. On separating the cotyledons, a small bud-like projection is seen; this is called the *plumule*, and it consists of extremely minute leaves. At the base of the plumule is the *corcule*, or germ of the future plant. From the lower part of the corcule tapers an elongation, which, during the process of germination, is termed the *radicle*, and is subsequently developed into the root. The corcule is connected with the cotyledons, from which it derives its nutriment, by suitable

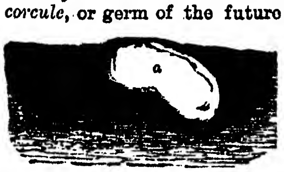


Fig. 4.—GARDEN BEAN. *a*, Testa or outer covering.

When the seed is placed in the soil, and supplied with the heat and moisture necessary for germination, that process soon takes place. The seed absorbs moisture, becomes soft, increases greatly in size, and finally bursts. The temperature at which this first effort of the vital force takes place is different in the case of different plants; for all varieties it must be above 32° Fahr. The seeds of the plants of temperate climates require, with few exceptions, a temperature of at least 40°; whilst the seeds of tropical plants do not in general germinate under 70°. According to Sachs, plants do not vigorously when produced from seeds which have been germinated at a low temperature; on the other hand, seeds germinated at too high a temperature do not produce healthy plants.

When the testa bursts, two shoots issue from the seed: one—the plumule—springs upwards, and is gradually developed into the stem of the plant; whilst the other, sinking into the soil, becomes in time the root (Fig. 5). During these changes, the composition of the seed undergoes important alterations. Its insoluble starch is converted into soluble sugar and a gum-like substance termed *dextrine*, with which the young plant is chiefly nourished. The albuminoids, or nitrogenous matters originally present in the seed, also are employed in feeding the young plant, and they gradually disappear from the seed. The cotyledons being thus deprived of the great bulk of their starchy and albuminous constituents, sometimes perish; but very often they make their appearance over ground, acquire a green colour, and for a brief time discharge the functions of leaves (Fig. 6).

Fig. 5.—GARDEN BEAN GERMINATING. *a*, Cotyledon: *b*, Plumule; *c*, RADICLE.

When the cotyledons begin to act upon the atmosphere, the independent existence of the young plant commences. Up to this point oxygen gas is absorbed, and carbonic acid gas exhaled; but in future the plant will absorb carbonic acid and exhale oxygen. The great bulk of the seed is made up of starchy matter, which, being insoluble, is not capable of nourishing the plantlet. There are also present in the seed albuminoid bodies—substances containing nitrogen—which are very liable to enter into a state of fermentation. During germination a portion of the nitrogenous matter ferments, and becomes the peculiar substance termed *diastase*, which possesses the property of converting starch into sugar and dextrine. It is stated that one part of diastase is capable of converting 2,000 parts of insoluble starch into soluble dextrine and sugar. This curious attribute of diastase is common to the albuminoid bodies found in plants; they are termed *ferments*. The albuminoids are like starch, insoluble in the ungerminated seeds; but during fermentation they become more or less soluble, and thus contribute to the nutrition of the plantlet.

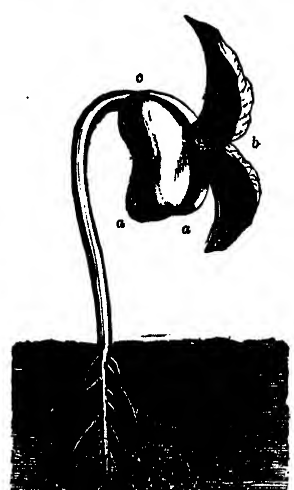


Fig. 6.—GERMINATION OF GARDEN BEAN IN ADVANCED STAGE. *a*, Cotyledons; *b*, Plumule; *c*, Corcule.

So soon as the young plant has exhausted the stores of organic food supplied by its parent, it enters upon the second stage of its existence, and now begins to *vegetate*. Henceforth it must depend upon air, soil, and water for its existence, and it must elaborate these mineral substances into the various tissues of its structure. We shall now explain the nature of the mineral food of plants, and the means by which they absorb it.

We have already stated that the great bulk of vegetable matter is composed of the elements oxygen, hydrogen, nitrogen, and carbon. These elements exist in the air—carbon as carbonic dioxide (carbonic acid, a compound of twelve parts of carbon with thirty-two parts of oxygen); hydrogen as water (hydric oxide, composed of two parts of hydrogen united with sixteen parts of oxygen); nitrogen in a free state and in the form of ammonia (a compound of fourteen parts of nitrogen and three

parts of hydrogen); and oxygen free and (combined with hydrogen and carbon) in the forms of water and carbonic acid. The greater part of the food of plants is undoubtedly supplied by the atmosphere, but it would appear that the free oxygen and nitrogen of the air are not assimilable by plants. Were the free nitrogen of the air capable of furnishing plants with the amount of this element which they require, there would be no necessity for applying ammoniacal manures to our soils. Before further considering this point, we shall state the composition of the atmosphere which surrounds our globe, extending to a height of at least forty-six miles from its surface.

AVERAGE COMPOSITION OF THE ATMOSPHERE.

		Parts.
Essential	Nitrogen	77·95
	Oxygen	20·61
	Watery vapour	1·40
	Carbonic dioxide	·04
	Ozone	traces
	Ammonia	
Non-Essential	Nitric acid	
	Carbonic oxide	
	Carburetted hydrogen	
	Sulphuretted hydrogen	
	Organic and solid mineral matters	
		100·00

According to Ville, there is but one part of ammonia in 28,000,000 parts of air; but Angus Smith found a larger proportion—one grain in 412·42 cubic feet—in the air of Manchester. Small as this proportion of atmospheric ammonia is, it appears to be sufficient for the purpose of supplying uncultivated vegetables with sufficient amounts of nitrogen. In the case of most kinds of cultivated plants, it is, however, found necessary to supplement the atmospheric ammonia with nitrogenous manures, such as Peruvian guano, ammonic sulphate (sulphate of ammonia), sodic nitrate (nitrate of soda, or cubic nitre), and the various "natural manures" obtained in the farm-yard and elsewhere. By the decay of organic matter in the soil, ammonia and nitric acid are produced, and both are sources of nitrogen to vegetation. Nitric acid is formed in the atmosphere by the oxidation of ammonia under electrical influences; and every year several pounds' weight of this substance descends upon every acre. Potassic cyanide (cyanide of potassium) is capable of yielding nitrogen to plants, as is also, as I have shown ("Transactions of the British Association, 1857"), urea, the chief nitrogenous matter in fresh liquid manure. It has been contended that the soluble organic matters in the soil directly furnish nitrogen to plants; but the weight of scientific evidence is against this assumption, as it is also opposed to the statement that vegetables are capable of assimilating the free nitrogen of the atmosphere.

The absorption of carbonic dioxide by plants takes place chiefly through the "breathing pores," or *stomata*, of their leaves. In agricultural plants the stomata are nearly altogether found on the under side of the leaves; they are very numerous, the leaves of some species of plants containing more than 150,000 per square inch of surface. The stomata communicate with the intercellular spaces in the plant, and consequently the air has ready access through them to the interior of the vegetable mechanism. It is chiefly by means of the stomata that the excessive water absorbed by the root is exhaled; and through these openings the gas generated within the plant, and not required for its nutrition, is got rid of.

Plants cannot grow in the dark. Fungi *appear* to be exceptions to this rule, but they are not in reality, for they cannot grow in the absence of light, except at the expense of the juices of other kinds of vegetables. The carbonic dioxide, water, and ammonia, taken into the vegetable mechanism, are decomposed under the stimulus of the solar beams, and their elements organised into the various structures and products of the plant. All the oxygen taken into plants in the form of carbonic dioxide is not required, and therefore a large proportion of it is exhaled through the stomata into the atmosphere. Carbonic dioxide is a poisonous gas to animals, whilst oxygen is the vital principle of the air which they breathe. Plants, therefore, by absorbing carbonic dioxide and exhaling pure oxygen, act as purifiers of the atmosphere; while, on the other hand, animals, by inspiring oxygen and expiring carbonic dioxide, indirectly contribute in an important manner to the nutrition of the vegetable creation.

The stomata have contractile powers, which subserve useful purposes. For example, under the influence of a dry atmosphere, the size of these openings decreases, and thereby prevents too rapid an exhalation of moisture from the plant. Moisture is indispensable to vegetable life; and if growing plants were deprived of all, or nearly all, the water which they contain, they would speedily perish. Under the stimulus of light the stomata increase in size, and absorb more carbonic dioxide. Plants grow, other conditions being equal, in proportion to the amount of the sun's light and heat which they receive.

The mineral or ash ingredients of plants are absorbed through the roots. Some of these ingredients—the alkaline salts for example—are soluble in pure water; others—such as, for instance, calcic phosphate—require for their solution water containing carbonic dioxide, and certain saline matters which increase the solvent power of water. The water contained in the soil holds in solution carbonic dioxide, and other matters, by means of which it is enabled to dissolve all the mineral substances required by plants. The term *spongioles* has been applied to the fine points of the branches of the root, and until recently it was the belief of vegetable physiologists that absorption of water and other matters took place only through these fibril or rootlet terminations. Ohlert, however, has shown that the real absorbing surface is close to, but not actually at, the tips of the roots. Every part of the roots, the *epidermis* or covering of which is young, thin, and soft, appears to be more or less capable of absorbing plant-food, but they have not pores corresponding with the stomata of the leaves and stems.

The green colour of the leaves and stems of plants is due to the presence of a pigment termed *chlorophyll*. When the green colour of the leaves disappears, the growth of the plant is wholly or in part arrested, and the inorganic forces are at work. The parts of the plant engaged in the absorption of carbonic dioxide possess colour, generally green. When parts of growing plants are kept in darkened situations, the formation of chlorophyll is prevented. It is by this means that the blanching of that favourite esculent, celery, is effected.

TECHNICAL DRAWING.—VII.

WOODEN BRIDGES (*continued*).

At each end of the piers in the water, in cases where several rows of piles are driven, a sort of cutwater should be formed, in order to ward off heavy bodies, such as floating trees, ice, etc., and prevent them from injuring the superstructure (called in German constructions, "Eisbrecher," or ice-breaker). This is usually done by driving one pile by itself in advance of the rest, or by forming what is called a "dolphin" at each end of the pier.

The piers and abutments should, of course, be made in every case sufficiently strong to resist the thrust of the arch. In the case of small bridges, where the distance between the supports is sometimes as much as twenty or thirty feet, longitudinal scarfed girders may be laid upon the caps of the piles. Under such circumstances, as we have seen, there is nothing but the weight or perpendicular pressure to be provided for; and the same may be said of timber bridges of greater width for roads, and even for railways, provided the distance between the piers does not greatly exceed ten or fifteen feet. Beyond that opening, however, bridges are usually sustained by struts or tension-rods, or the roadway timbers are trussed so as to exert an oblique pressure upon the supports; indeed, in all instances of the kind, where the bays are formed upon the principle of compression or tension, the piers must be so formed as to counteract the tendency constantly exerted to force them out of their perpendicular position. This must be done either by making the piers of sufficient weight and strength to overcome any force that may be exerted against them, or else to counterbalance the efforts of one bay or arch acting in one direction, by a similarly acting arch or timber frame exerting a like amount of force in the contrary direction. The former of these methods is employed in the abutments of

a bridge, whilst the latter is invariably adopted with respect to piers.

The roadway of timber bridges is usually a flooring of boards laid upon the joists, for, in cases where sand and stones are employed, it is found that their weight, together with the humidity they engender, causes the timbers of such bridges speedily to decay. This, however, is far from being a general rule, and many splendid erections of this description are rapidly being destroyed, owing to a want of attention to this important particular. Some have proposed to cover the surface of the roadway with lead, iron, copper, etc., but the increased expense will be a great obstacle to their frequent introduction. Wood pavement forms an excellent covering for timber bridges, and is highly recommended by various engineers.

The parapet, or hand-rail, of these bridges is frequently of wood, or it may be of cast and wrought iron. Now, however, that it has been shown how important an addition to the strength of a bridge the sides of a beam are, and that it acts usefully in the direction of its depth, if it has only sufficient breadth to prevent its yielding laterally, it ought in every case to be made available to sustain the bridge, in addition to its present purposes of ornament and protection.

Fig. 32 is one of three bays of a wooden girder bridge, which is the simplest class of such constructions, consisting merely of beams laid across the stream and supported by piers formed of wooden framework, from which struts spread out on either side, which extend the bearing effect of the piers, and so diminish the length of the girder which is left unsupported.

In copying this example first draw a horizontal line, to form the top of the elevation of one of the cross-pieces, which, resting on purlins, clamp the piles forming the piers between them.

As this portion of the structure is shown on an enlarged scale in Fig. 36, the lettering here given will apply to that illustration. *a′ a′*, then, is the front elevation of the pile against which the struts, *d*, are firmly bolted, and on to these the purlins, *f*, are notched. These struts, too, are halved on to the pile at their upper ends, so that they clamp it between them. This arrangement is shown in Fig. 37, which is the side elevation.

Returning, then, to the drawing (Fig. 32), the horizontal line drawn is to be the top line of the cross-beams, which in Figs. 36 and 37 are lettered *c*. Now, in the front elevation these are seen in section; but, as you will require the same height in the cross-section (Fig. 33), draw this line of indefinite length at once; and this system of projecting one view from the other is to be carried on throughout, as thereby much time will be saved, and greater accuracy ensured, for it is by far easier to continue a line at once than to "piece" it afterwards.

Next draw a second horizontal line under the other, at such a distance from it as to give the lower edge of the cross-pieces, *c*, and then, having drawn the irregular line representing the bed of the stream, draw the vertical lines, which will form the sides of the struts, *d d* (seen in *front* elevation).

Now, on referring to the cross-section (Fig. 33), it will be seen that precisely this same arrangement exists in regard to the middle pile—namely, that it is clamped between two cross-pieces, and against these two struts abut. These cross-pieces are shown in section in Fig. 33, the struts being merely represented by the three perpendicular lines under these. They are, however, shown in elevation in Fig. 32, where their effect of adding to the steadiness of the frame will be evident.

The foundation of the pier being thus completed, next draw the uprights and the cross-timber resting upon them. This is shown in its full length in Fig. 33, and in section on each of the piles in Fig. 32. The upper line of this cross-timber will, of course, form the lower line of the main girders resting upon the cross-pieces. Now draw the upper edge of these girders, which, of course, are seen in elevation in Fig. 32, and are represented by seven shaded squares in Fig. 33, these squares representing the sections of the seven ribs, which will thus be seen to be made of square timber. Each of these girders rests immediately on a pile, so that the bridge is supported by seven ribs. You will now draw the struts, and as these are here placed at an angle of 45°, you can use your set-square, or, of course, you can find the exact inclination, whatever that may be, by measuring the distances of the upper and lower ends of the strut from the right angle. These struts are now to be added to the cross-section (Fig. 33), from which it will be seen that they are narrower in this direction than in the other.

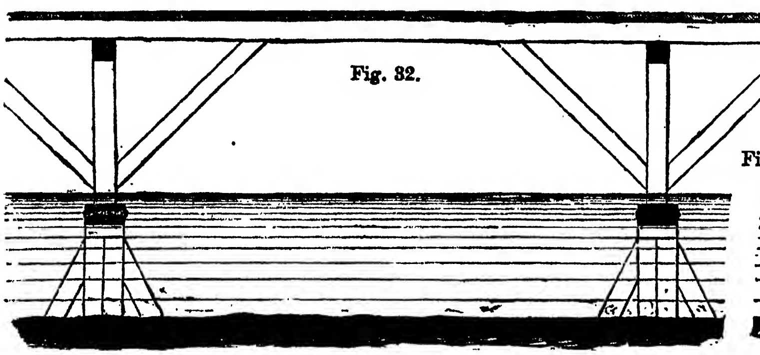


Fig. 32.

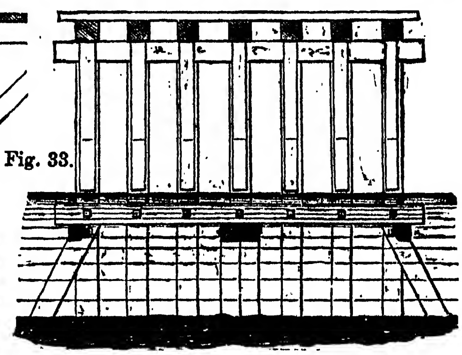


Fig. 33.

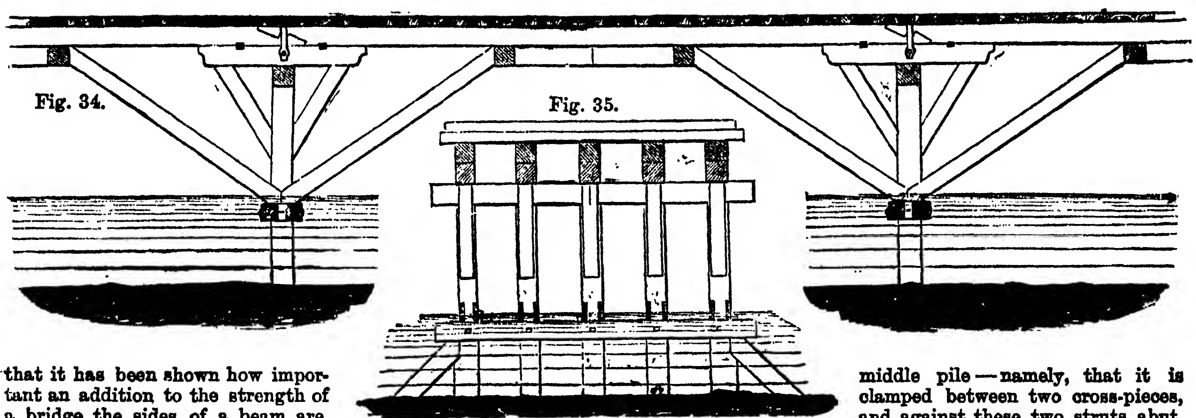


Fig. 34.

Fig. 35.

The horizontal line forming the top of the flooring of the bridge is now to be drawn, and as these planks, of course, run at right angles to the girders, their ends are shown in Fig. 32, whilst their length is shown in Fig. 33.

Fig. 34 is an example of a bridge in which the struts abut against centre-pieces, placed on the under side of the girders. They do not, however, touch these centre-pieces directly, but

Fig. 40 is an illustration taken from a five-bay girder bridge in Germany. This is supported on stone abutments and piers, the bearing of which is extended, first, by two saddle-pieces, the upper projecting below the under one, which, in its turn, projects beyond the pier. Next, the bridge itself is formed of double girders, one above the other. Now the upper one is supported by struts, which are shown in the longitudinal sec-

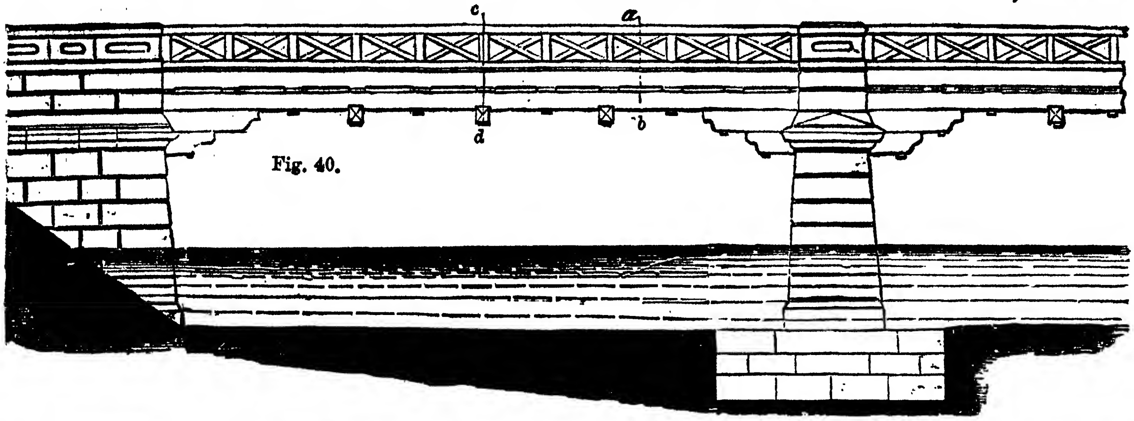


Fig. 40.

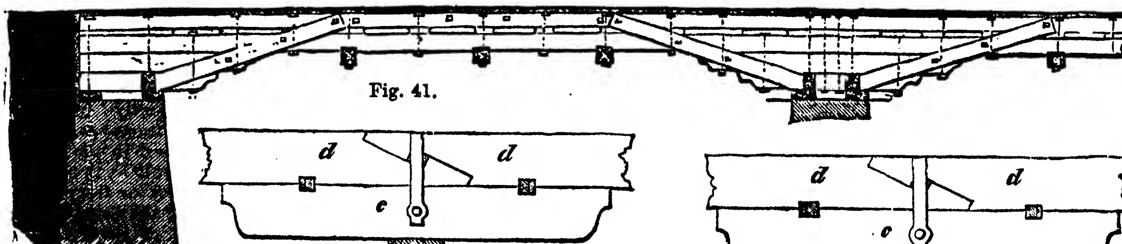


Fig. 41.

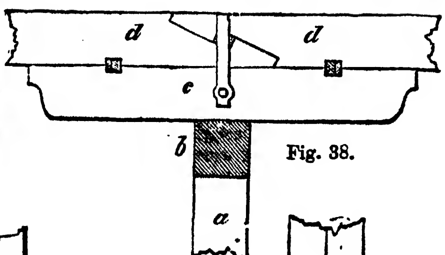


Fig. 38.

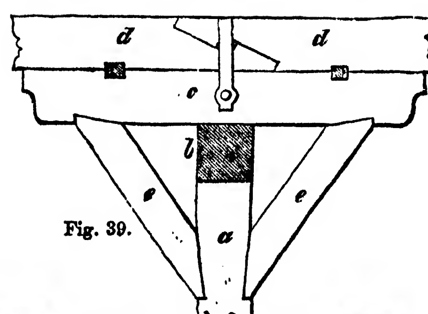


Fig. 39.

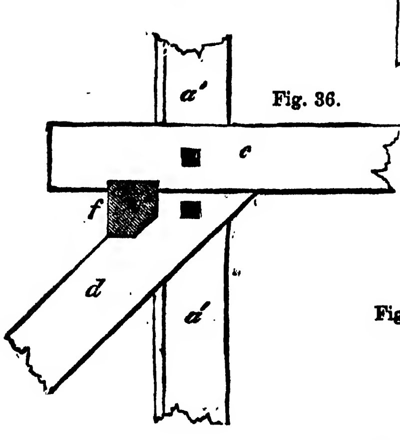


Fig. 36.

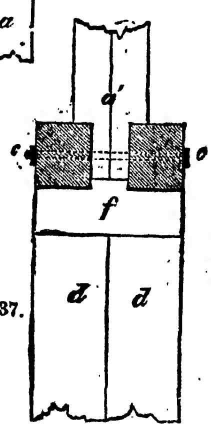


Fig. 37.

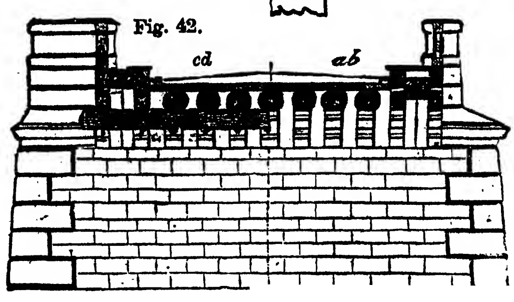


Fig. 42.

cross-timbers, the sections of which are shown in the elevation, are placed as end-ties, and against these the struts abut.

The heads of the piles are united by a waling-piece, on which, over each pile, a saddle-piece rests, supported by struts. This gives a much broader surface on which to rest the girders, which are scarfed at this point.

In drawing this bridge, the system is precisely similar to that adopted in the former example, and therefore no further explanation need be given.

Figs. 38 and 39 are examples of scarfing the girders, and of the methods of supporting them. The latter method is that adopted in the preceding study. The subject of scarfing will be treated in "Building Construction."

tion (Fig. 41), and as cross-timbers passing transversely beneath the lower girders are bolted through to the upper ones, the lower girders may be said to be suspended from those above them.

From Fig. 42, which is a transverse section on the line $a\ b$, it will be seen that the footway is raised to a higher level than the roadway by means of square timbers resting on transverse beams. The roadway is laid upon round timbers, which are extensively used in Germany.

Although only one bay is given in the example, the student is advised to draw more than this (of course to a larger scale), as the practice thus obtained will be of great service to him.

In commencing, rule a straight line for the bed of the river, and draw the foundations and embankments. Next erect per-

pendiculars on the middle of the foundations, to act as centre-lines for the piers. On these perpendiculars, mark off the heights of the cornice and capping of the piers and abutments, and draw the required horizontals; on these, mark off the respective widths from the centre-line, and complete the piers both above and below the capping.

The profile (or side view) of the abutment now requires our attention, the next task being that of drawing it at the same slant as the sides of the piers. Now, in this bridge the space between the abutment and the pier is the same as that between any two of the piers; therefore, measure that distance from *centre to centre*, and from the central perpendicular of the last pier mark off this distance on either of the horizontals, and through the point thus obtained draw a perpendicular, which will be to the profile of the abutment as the central perpendiculars are to the piers; therefore, proceed in the same manner to set off half the width of the pier on the horizontals, and thus complete the abutments.

The double saddle-pieces resting on the piers and abutments are to be drawn next, and then the double girders.

ANIMAL COMMERCIAL PRODUCTS.—IV.

RUMINANTIA (*continued*).

The skin of the lamb is made into collars, muffs, gloves, and coat-linings. The most valued of these skins are furnished by Southern Russia, Greece, and Hungary. Beautiful black lamb-skins are imported from the Crimea, and others still more rich and glossy, with a short fur, from Astracan. The lamb-skins from Persia are known by the curl of the hair, which is produced artificially by tying up the lamb, as soon as born, in a leathern skin, and thus preventing the hair from expanding. These Persian lamb-skins are used for coats and other garments.

The skin of the fœtal calf is used for covering trunks.

The principal fur marts for the English or Canadian furs are London, in Upper Canada; Fort William, on Lake Superior; and in Lower Canada, Montreal, on the River St. Lawrence.

II.—PERFUMES.

The Musk Deer (*Moschus moschiferus*, L.; order, *Ruminantia*).—This animal, which furnishes the well-known perfume called musk, is about the size of a roebuck, without horns, legs very slender, and in all its movements exceedingly active and graceful. The musk deer is found in herds in the mountains of Central Asia, and in some of the larger islands of the Indian Ocean, such as Ceylon, Java, Sumatra, and Borneo. It is a shy animal, fond of precipices and almost inaccessible crags, and therefore very difficult to shoot. The musk is produced in a glandular pouch in the abdomen, and is peculiar to the male. It is in the form of reddish-brown coarse granules, and greasy to the touch. The average quantity which can be removed from one pouch is about 190 grains.

Musk is known in commerce under two forms—as Tonquin or Thibet musk, which is the most valuable, and Siberian, Kabardinian, or Russian musk, of inferior quality. The Oriental or Tonquin musk, from Cochin-China and Tonquin, is imported in small oblong, rectangular boxes, which are lined with lead, to prevent the escape of the odour; the musk bags, wrapped in thin blue or red paper covered with Chinese characters, are placed in these boxes. These musk bags are usually covered with hairs, which all converge towards the little narrow opening in the bag. The weight of each bag varies, some not exceeding half an ounce, whilst others weigh upwards of two ounces. Large numbers of musk deer are annually killed. The annual import of musk into the United Kingdom is upwards of 10,000 ounces.

Besides these uses, musk also possesses valuable remedial qualities. When genuine, it is one of the most powerful of the anti-spasmodics, and is applied with advantage in cases of infantile spasms, when not accompanied with inflammation.

Civet Cat (*Viverra civetta*, Gmelin: order, *Carnivora*).—A native of Northern Africa, and especially common in Abyssinia, allied to the pole-cat and marten. Body from two to three feet long, and from ten to twelve inches high; tail half as long as the body. This animal yields a perfume which is thus obtained:—The civet, when captured, is enclosed in a small cage, in which it cannot turn round, and while thus confined, the secretion is removed from its large anal pouch two or three times a week with a spoon or spatula. The interior of the pouch is glandular, the glands secreting the perfume from the blood of the animal. The substance itself is of a pale-yellow colour, and of the consistence of honey. It is not unlike musk, and to most persons smells disagreeably; but when mixed with butter, wax, lard, and alcohol, in the proportion of 1 part to 1,000, it loses its offensive character, and becomes aromatic and delicately fragrant. Thus prepared it is used in perfumery, and when employed renders more perceptible other scents with which it is mixed. Lavender and other scented waters become more agreeable by the addition of minute quantities of civet. The substance is not so much in use now as formerly; nevertheless, there is still a considerable consumption of it in this country, and as much as forty shillings an ounce is paid for it.

Viverra zibetha is another species of civet cat, peculiar to the Asiatic continent, and found from Arabia to Malabar, and in the larger islands of the Malayan Archipelago. It is much milder in its disposition than the African species, and is domesticated by the Arabs and Malays. Our supplies of civet are also derived from this animal, although to a less extent than from the African species.

Castoreum, which strongly resembles musk in its medicinal qualities and applications, is furnished by the beaver (*Castor fiber*, L.). This substance is secreted in the interior of a little bag or pouch, with which the beaver is supplied. It is brought to market, like the musk, in the pouch. The best *Castoreum* is that from Russia and Siberia; a very good quality is furnished also by Poland, Prussia, Bavaria, Germany, Sweden, and Norway; an inferior kind comes from Canada and the territories formerly belonging to the Hudson's Bay Company.

Ambergris.—This substance is obtained from the sperm whale. It is an expensive drug, because not frequently found, and is valued on account of the excellency of its fragrance. Ambergris is a morbid or diseased concretion formed in the stomach, or probably in the gall-ducts, of the sperm whale, in masses of considerable size, sometimes weighing thirty or forty pounds. It is usually found floating on the surface of the water, probably disengaged from the floating body of one of these monsters, and is rarely sought for in the intestines of the sperm whale, although it is worth a guinea an ounce. It is fished up in the Indian Ocean, near the Moluccas and Philippine Islands; also near Sumatra, Madagascar, and on the coast of Coromandel. In the Atlantic Ocean it is found near the West Indies and the Brazils. Ambergris is used as a costly frankincense, principally for perfumes, especially in France. It has also the property of increasing the power of other perfumes when mixed with them, and it is principally for this purpose that it is used.

OPTICAL INSTRUMENTS.—I.

By Samuel Highley.

SPECTACLES—THE NORMAL EYE.

One of the first offices the optician is called on to perform is to aid humanity, when through age, defect, or absolute disease, the organs of vision deviate from the very perfect optical arrangement that characterises the normal eye.

The Normal Eye.—Every perfect (or as it is technically termed, *normal*) eye possesses the power of "*accommodation*," that is, of adjusting itself for different distances, now looking at something near, as a book at reading distance, then at some far distant object, presently taking in at a glance the range of an extensive view.

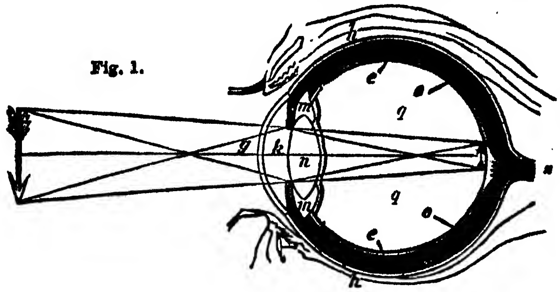
In a normal eye the whole apparatus of accommodation is so beautifully balanced, its functions performed with such ease and accuracy, that although in reality a voluntary act, its duties are from early childhood fulfilled intuitively, imperceptibly, and unconsciously.

A familiar exemplification of the power of accommodation may be made by placing one object at a yard distance from the eye, and another at six yards beyond it; on looking intently at either *we are conscious of the presence* of the other, but we do not discriminate its details; on fixing one, we lose the definition of the other. Again, if the letters of a book, held at some distance from the eye, be looked at through a gauze veil placed

nearer the eye, it will be found that when the letters are seen distinctly the veil will be seen indistinctly; and conversely, if the veil is seen distinctly, the letters will be seen indistinctly. These experiments demonstrate that images of objects at different distances from the eye cannot be defined *at the same time* upon the retina.

The human eye is a camera obscura, furnished with an achromatic lens, compounded of three principal parts, namely, the *aqueous humour*, *k* (Fig. 1), held in place by a transparent horny capsule, the *cornea*, *g*; the *crystalline lens*, *n*, the principal refracting medium; and the *vitreous humour*, *q*, which

Fig. 1.



constitutes the main body of the eye, in which optical combination the *iris*, *m*, placed between the aqueous humour and the crystalline lens, plays the part of a self-adjusting diaphragm; the circular opening or "stop" in the pupil expanding when the light is feeble or the object viewed is distant, and contracting as the light becomes more and more intense or when the object viewed is near. This compound lens projects an *inverted* image of an object on the *retina*, *o*, which corresponds to the focussing glass of the photographer's camera. The retina is a delicate and sensitive network of nervous filaments springing from the *optic nerve*, *x*, that conveys to the brain the impression of an image focussed on the retina. The *sclerotic*, *h*, a tough white membrane, forms the wall of the eye, and corresponds to the *rigid* box of a camera, and to this wall are attached the various muscles that (like the hands of the photographer) direct the eyeball to the object. The sclerotic is lined with a delicate membrane, the *choroid*, *e*, coated on its inner surface with black colouring matter (*pigmentum nigrum*), shown behind *o*, which serves the same purpose as the black paint or velvet on the inside of a camera, viz., to reduce to a minimum all internal reflections.

So far the comparison between the eye and a camera is perfect, but here the parallelism of properties ceases. In the ordinary camera the image of an object is received on a flat plate of glass; but, as a consequence of every lens being subject more or less to the defects of spherical aberration, if the central portion of the object is perfectly depicted on the screen, the marginal portion will be distorted and indistinct, through the marginal rays emanating from that object being blurred by the focal point falling short of the focussing glass; conversely, if the marginal rays are brought to focus on the screen, the central portion of the image will become indistinct through being out of focus. In the human eye, however, the retina being the most perfect form of focussing screen that could be designed—viz., hemispherical or basin-shaped—the delineating rays fall on its surface in the precise ratio of their lengths.

In the above general description of the component parts of the human eye it is stated that the external walls or sclerotic correspond to a *rigid* camera, that is to say, one wherein the box is not made with a telescopic draw, to obtain facility for focussing near and distant objects. In a telescopic camera, on pointing the lens to a near object, we have to draw the focussing glass away from the lens to secure a sharp image on the ground-glass screen (or retina of the camera), while on pointing to a distant object we must push the screen nearer the lens to obtain the same result. Now it might be supposed that the act of focussing (or power of "accommodation," as it is termed) was obtained through the elasticity of the walls of the eyeball (acted on by sympathetic muscular power), in the one case elongating, in the other contracting in length in the direction of its axis; but this is not the case. Great has been the discussion among physiologists as to the exact means by which the accommodation of the eye to far and distant objects is really effected, but general opinion at the present day is in favour of the view that it is through curvature of the crystalline lens being increased when near objects are viewed, and decreased when distant objects are observed, and further by its change of relative distance between the iris and retina.

The experiments of Dr. Young on persons deprived of the crystalline lens, and who were thereby incapacitated from focussing their sight, seemed to put the question of the power possessed by this portion of the eye beyond dispute; while the subsequent investigations of Cramer and Helmholtz have definitely settled it.

When the normal eye in a state of rest is adjusted for an object, D, at an *infinite distance** (at or beyond 18 feet from the eye), the rays emanating from such an object being parallel are brought to a focus on the retina (as shown at *i*, Fig. 2) without any effort of accommodation; but when an object is viewed at a *finite distance*, N (say, 12 inches from the eye), the rays emanating from such an object becoming then divergent, they will no longer be brought to a focus on the retina, but to a point behind it, as at *f* (Fig. 2), if the eye does not undergo some change which will increase its refractive power, and bring these divergent rays to a focus upon the retina. The normal eye does by its power of accommodation effect such a refractive process, and, as Helmholtz found, by means of his ophthalmometer, in the following manner:—

1st. The pupil diminishes in size.
2nd. The pupillary edge of the iris moves forward.
3rd. The peripheral portion of the iris moves backwards.
4th. The anterior surface of the crystalline lens becomes more convex (and so acquiring a higher power of refraction, and consequently a shorter focal length), and its vertex moves forward.
5th. The posterior surface of the crystalline lens also becomes slightly more arched, but does not perceptibly change its position; the lens, therefore, becomes thicker in the centre.

And from calculation he found that these changes in the crystalline lens are quite sufficient to account for all accommodative purposes.

The diagram in the next page, after Helmholtz (Fig. 3), shows the changes which the eye undergoes during accommodation. The anterior portion is divided into two equal parts: the one half, I, shows the position of the parts when the eye is adjusted for distance; the other, F, when it is accommodated for

Fig. 2.

near objects. When the eye is in a state of rest, the iris forms a curve at *a*; when accommodated for near objects, the fibres of the iris become contracted, the periphery of the iris straightened at *b*, and the anterior chamber lengthened, thus making up for its loss in depth, through the advance of the anterior surface of the crystalline lens. The anatomical mechanism by which this accommodation is effected is yet an open question, but as it is one of physiological rather than optical importance, it need not be herein discussed.

* The rays emanating from a far distant object, such as the sun, moon, or a star, are regarded optically as parallel, but practically, even when an object is only placed at eighteen or twenty feet distance, the rays from it, though really divergent, are yet so slightly so, that to all intents and purposes they impinge parallel upon the eye. We therefore consider rays coming from an object further than eighteen feet as parallel, and emanating from an object at an *infinite distance*. On the other hand, rays coming from a nearer object fall upon the eye in a divergent direction (the divergence being in proportion to its proximity), and are then considered as coming from a *finite distance*.

It is assumed that when the normal eye is in a state of absolute rest, parallel rays (emanating from objects at an infinite distance) are brought to a focus on the retina, and that a positive change in the accommodative apparatus of the eye is only required for objects at a finite distance; but it is thought by some ophthalmists that the eye when in a state of rest is adjusted neither for its far nor for its near point, but for a distance between the two, and that adjustment for either nearer or more distant objects necessitates an effort of accommodation. Such authorities call the adjustment for near objects *positive*, and that for distant objects *negative* accommodation.

It may be here noted that every eye has its "*blind spot*," which is situated at the point where the optic nerve enters the eye, and from which it ramifies to form the network of the retina; and if the image of an object is made to fall upon that spot it will be invisible, as the *punctum cæcum*, as it is called, is insensible to the action of light. This may be proved in the following manner:—Lay two black wafers on a sheet of white paper three inches apart, and at a distance of ten or eleven inches, bring the right eye exactly over the left-hand wafer, so that the line joining the two eyes shall be parallel to the line joining the two wafers. On closing the left eye, and looking steadily with the right at the left-hand wafer, the right-hand one ceases to be visible, as in this position its image falls upon the "blind spot."

Fig. 3.

As the normal eye performs its delicate functions to perfection, it is evident that the interference of the optician can never be required, excepting to give relief when the organs of vision are weak or suffering from inflammation, in which case an ordinary spectacle-frame fitted with a flat piece of tinted glass may be furnished to the patient; or when it is necessary to carry this protective appliance to greater perfection, a frame may be supplied with what are called "*glazed wings*," shown in Fig. 4, while the most perfect guard is to be found in a frame fitted with tinted glasses and a shield of fine black gauze that fits close around the socket of the eye, shown in Fig. 5.

The glass employed in the construction of these "Protectors" may be obtained of various colours and tints, green and blue being chiefly employed; but the tint that admits the ... and yet allows of the greatest amount of ... eutral blue, the value of which has been recognised by most ophthalmic surgeons and oculists.

Tinted protectors of this nature may also be given with ... to travellers to guard them against the injurious reflections from Alpine snows or ... sands, very dark glasses, they may also be recommended to those who have received injury to the eyes, in order to disguise the disfigurement.

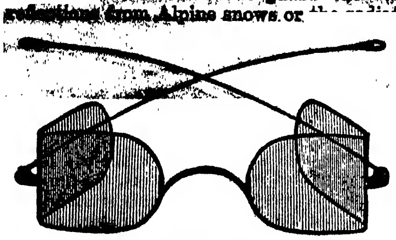


Fig. 4.

In violent or in chronic inflammation of the eyes the optician is often applied to for a shade that will give more ventilation than the home-made article will allow of; the best arrangement is one wherein the shade is supported on the head by a metal frame in such a manner as to throw the upper edge of the shade slightly from the forehead so as to allow a current of air to pass over the eyes, while by a pivot attached to the frame the shade can be thrown back when necessary.

The optician is also often required to furnish an "eye douche," by which the organ can, in certain cases of irritation or weakness, be bathed. These usually consist of an elastic syringe, by which water or medicated liquid can be projected on the eye with any amount of force, connected by an india-rubber tube with a glass cup that surrounds the eye while being used, and to this cup another tube is attached to carry off the liquid into a basin. Where the eye is to be subjected to the influence of stimulating vapours, a stoppered bottle, constructed with an oval-shaped cup to fit the socket of the eye is employed.

The optician is frequently requested to supply eye-glasses or spectacles to persons who, they soon discover, are in no way affected in their organs of vision—in fact, are blessed with a normal eye. As a rule, such individuals desire what may be called a "dandy glass" to stick in their eye-sockets, with which to assume a supposed fashionable appearance, and further, that this shall be supplied at the lowest possible price. The article best suited to meet the want in such cases is a disc of *plane* white glass with a hole drilled in it for the insertion of a thin silk cord, by which it can be attached to the person. It need scarcely be stated that such a glass must be perfectly devoid of all optical properties. In other and similar cases spectacles are desired to give the wearer a thoughtful or learned appearance; in such instances two plain glasses (not lenses) are required instead of one, which might be called "snob glasses." In rare cases it may be found that aged persons of good constitution are desirous of purchasing a pair of spectacles, not from any absolute shortcoming of sight, but from a notion that as friends of similar or greater age required the optician's aid, *they* also *ought* to wear them. In such instances the applicants may be tested with convex and concave lenses before the real state of the case is discovered, as they see better with the naked eye than with spectacles of the lowest power. The proper course is to state that spectacles would do more harm than good, a piece of advice that would be quite thrown away in the former cases.

Range of Accommodation.—When the eye has assumed its highest state of refraction, it is accommodated for its *nearest point* of distinct vision; when, on the other hand, its state of refraction is relaxed to the utmost, it is adjusted for its *furthest point*.

The distance between the furthest and nearest point of distinct vision is called "*the range of accommodation.*"

As increase in the convexity of the crystalline lens is limited, its power of accommodation for near objects is also limited, and the "*near point*" cannot be brought nearer than a certain distance to the eye. In normal eyes the nearest point of distinct vision lies at about 3½ inches to 4 inches from the eye; this varies, however, according to age, for the near point recedes further and further from the eye with increasing years.

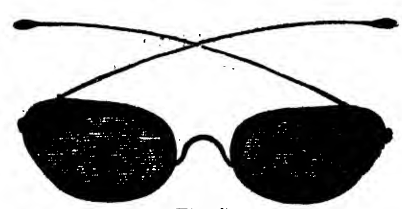


Fig. 5.

Where professional occupation, such as engraving, needlework, etc., necessitates continued work at near objects, the near point for distinct vision lies at about five inches from the eye. Few eyes, it should be observed, can bear to work for any length of time with the object nearer than this.

The furthest point of distinct vision in the normal eye is at an infinite distance. The amount of this "range of accommodation" varies according to the strength of the ciliary muscles, the elasticity of the crystalline lens, and other minor causes. It is most important that the optician should carefully determine the "range of accommodation" for each patient according to the method hereafter given, as it affords a means of safely discovering whether the eye is normal, presbyopic, hypermetropic, or myopic, and the kind of lens exactly suited to each particular case, together with the most suitable focus for such lens.

CIVIL ENGINEERING.—II.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

DRAINING.

Works of drainage are of two kinds :—1st. Those which relate to the reclamation of land from the encroachments or accumulation of tidal and other large bodies of water. 2nd. Those which relate to the removal of sewage from towns. As respects agricultural drainage—by which we mean the improvement of the soil by the removal of mere surface moisture—as it does not come within the province of Civil Engineering, we shall make no further allusion to it.

The value of the land overflowed by tidal waters, or by waters subject to rise and fall through floods and drought, is almost always very considerable, owing to the marine or alluvial deposits which remain upon the soil. Some of the component parts of sea-water are highly fertilising; indeed, in many districts, especially in Scotland and Ireland, sea-weed forms the only manure employed by the farmer. Hence it has been found worth while to expend vast sums of money in order to shut out the water, and to drain the soil over which it had spread.

It is a matter of no ordinary difficulty to contend against the variations and alternations of pressure produced by water whose level is perpetually and rapidly changing. This difficulty reaches its maximum in the case of tidal waters, especially of such tides as are experienced upon British shores, where, in less than the space of twelve hours, there is a rise and fall of from fifteen to twenty-four feet. The immense rush of water in or out of any passage communicating with the tides, renders the greatest caution necessary, lest the barriers intended to withstand the pressure should be carried away before being sufficiently consolidated. And yet in the face of these engineering difficulties, a vast portion of the low land in Holland has been reclaimed from the sea; and in England upwards of half a million of acres of land in Norfolk overflowed at one period by the joint action of the sea, and the rivers Witham, Welland, Ouse, and others, have been converted into some of the richest agricultural districts in England, from being, at one time, pestilent marshes. How these particular results were brought about it is not our purpose to explain; our object is rather to state briefly the usual course adopted in operations of this kind. It is not, however, possible to lay down any rule of action, since each operation will require some special arrangements applicable to the particular locality; these matters must be left to the discretion of the engineer.

Before commencing a main barrier of any kind, whether of piles, earth, or caissons, it is desirable to ascertain, by a careful survey of the flooded districts and an examination of the levels, how far a judicious arrangement of canals and ditches may not avail to carry away a large amount of water by the mere effect of gravity, and also whether or not an ordinary dyke or bank of earth, stretched across a back-lying portion of drowned land, may not successfully diminish its area, and thus render less difficult the final operation of closing the entrance to the tide, when this has been reduced to a minimum by subsequent operations. These simple operations will frequently save an immense amount of labour, for it is obvious that the larger the area of the submerged land, the greater will be the rush or *scour* of the tide as it flows over it.

Whenever banks are erected across a flooded district, they should be constructed with *sluices* or *flood-gates*, which can be opened or closed when required, so that advantage may be taken of a lower state of the water-level upon the tidal or outlet side to disch[illegible] xcess upon the land side. It is also of [illegible] self-acting sluices or outfalls, which are simply strong doors or flaps of timber, iron-hinged at their upper edge, and opening only *outwards*, so that whenever the level is higher upon the land side, the greater pressure of water automatically opens these doors, and a discharge continues until uniformity of level is gained, when the doors close by their own weight, and falling against a *sill*, effectually prevent the return of the discharged water. These sluices, to be of most service, must be constructed low down in the dyke, and being usually out of sight, should be constructed with great care, as any derangement in them would cause disastrous results.

It frequently occurs that an accumulation of fresh water arises from the simple overflow of a river during heavy and continuous rains, or a sudden thaw. Such floods are of frequent occurrence in the south of France, and cause serious loss of property and life. The remedy in this case is simple and obvious, although it may involve a considerable outlay. The banks must either be raised and strengthened, or the channel must be deepened and widened, or additional channels must be cut; the end being in either case gained when the sectional area of the water-course is equal in every point to the volume of water which has to pass it in a unit of time.

In the case of tidal waters, the operations are very difficult; the rush of the *in*-flowing water at every flood-tide, and of the *out*-flowing at every ebb, and the consequent *scour* produced by this rush, has to be met, and the smaller the opening or gap, as compared with the tract of land covered at each tide, the greater will this rush be; and it is only a barrier far more substantial than it is possible to place across any large opening, in the short period allowed between tide and tide, that will suffice to withstand the force of the current in the tide-way. Hence it is necessary to reduce the width of the tide-way to a minimum before attempting to close it. The most substantial barrier, and the cheapest whenever it can be employed, is *earth*; but this is useless to stop an opening through which a violent rush of water occurs, as the soil will be carried away as fast as it is deposited. Earth can, however, be safely and advantageously employed as a base for further operations; using it in all cases where the flow of water is inconsiderable, and thus gradually narrowing the tide-way. When this embankment (strengthened according to discretion with piles) has been carried as far as it can be with safety, there then remains the tide-way to close up.

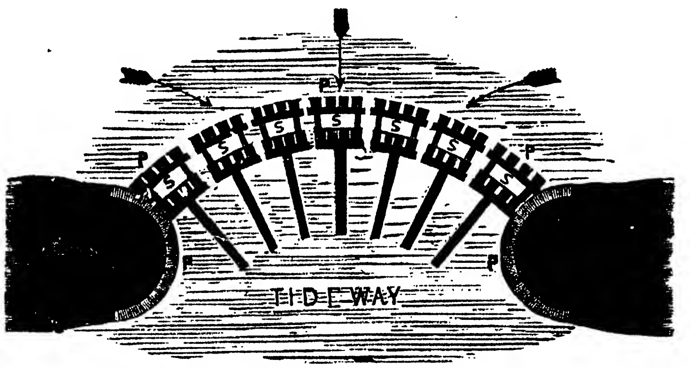


Fig. 1.—BARRIER AT THE MOUTH OF A TIDAL BASIN.

There are two methods of doing this. If the depth of water in the channel will admit of it, a double semi-circular or curved row of piles (P P P, Fig. 1) may be driven at short intervals apart across the opening, leaving a space (S S S) of twelve or eighteen inches between the two rows, which are to be strengthened by cross-ties, braces, and struts (T T T).

The curve must be outwards, and the driving of the piles should commence from each side and finish in the centre. At the ends of the curve, the piles abut upon other piles driven closely together, and forming a protection for the extremities of the earthen dyke, which would otherwise be subject to injury by the *scour* of the water. Barges of stiff, broken clay and stones should be floated near the outside of the piles, and plenty of labour ought to be at hand in order to take prompt advantage of the moment of low water. The clay and stones must then be rapidly shot into the space between the rows of piles; and if the organisation of labour be good, it will be quite possible to keep pace with the rise of the tide in the deposit of the soil, and even to impart a certain degree of solidity to it by ramming. Such a barrier has the elements of great strength in it; and although it may not be altogether impervious to water, it will suffice to prevent any considerable flow, and will entirely stop

a rush or scour, thus enabling the permanent embankment to be completed, after which the piles can be removed.

The plan we have indicated will not, however, avail in all cases. The depth of water in the tide-way may be too great to admit of piles being sunk sufficiently deep into the soil to gain a firm standing, or the area of the land overflowed at every tide may be so extensive, that it will be found impossible to narrow the tide-way by a continuous earthen embankment sufficiently to admit of a barrier of piles withstanding the pressure.

In such cases the following course may be adopted:—Let the embankment contain, at frequent intervals, large flood-gates, constructed during the progress of the work, which can be opened and shut at pleasure. When the gates are open, the flow of the tide is spread over an opening equal to the joint area of the space between the extremities of the embankment and that of the flood-gates, and will, consequently, be less in the unfinished opening when the gates are open than when they are closed. The scour of the tide being thus reduced, the embankment can be continued until the space of the tide-way is reduced to a point sufficiently narrow to admit of the same course being adopted as shown in Fig. 1. The embankment can then be completed, and the gates being closed at low tide, the level of water over the enclosed space will be proportionately reduced.

Under almost all conditions of the drainage of flooded lands, a surplus of water will remain even after all communication with the tide has been cut off, and this surplus must be removed or kept under by pumping. Wind or steam power may be necessary, indeed *will be*, if the submerged district is extensive.

The better kind of pump for the purpose is the "V," the "chain," or the "centrifugal," as the grit which enters the pump with the water is sure to act detrimentally upon the ordinary barrel and bucket pump, destroying the leather and choking the valves.

Constant attention must be paid to the sluices, "clows," and gates, owing to the great pressure they are frequently subjected to, and in consequence of the serious results which would ensue from their failure. An idea of the pressure exerted by water, when any considerable difference of level exists, is formed by the fact that, at the mean height of the tide—sixteen feet above low-water mark—the pressure exerted upon each square foot of surface at the bottom is 1,152 lb., and half this, or 576 lb., represents the actual mean pressure exerted by a high tide upon every vertical square foot of an embankment.

The magnificent stone embankment which has been constructed on portions of both the north and south sides of the Thames, and which has for its object, among others, the narrowing of the channel in order to cause a greater scour of water to remove the accumulated mud, was carried out behind a protecting wall of closely-fitting piles, in one portion, and of cast-iron shields, dovetailed together with piles, in another. The percolation or water from the river, which was considerable, was kept under by steam-pumps. The granite wall was completed behind the wall of piles, and soil afterwards "tipped" into the space on the land side. The foul black mud has thus been buried, and the space it formerly occupied devoted to a splendid carriage way, a subterranean railway, and one of the principal culverts connected with the main drainage system of the Metropolis.

***Sanitary Drainage.*—But one opinion can exist as to the necessity for removing sewage from the vicinity of an inhabited district, although a variety of opinions are held as to the best mode of disposing of it. It is foreign to our purpose to adduce the various arguments which have been raised for or against any particular system of drainage, and we shall merely state what are the various plans adopted.**

I. We consider the most desirable plan, when practicable, is entirely to remove the offensive matter as far as possible from the inhabited locality. This plan has been carried out at great expense in the drainage of London.

In all cases of sanitary drainage it is necessary to provide for the passage of rain-water as well as of mere sewage. An estimate of the rainfall in any particular locality, formed by taking an average of a succession of years, is hardly sufficient; it is better to select the *maximum* rainfall in one day of a series of years, and provide an excessive area in the culverts for such a maximum, so that no danger from the flushing of the sewers shall arise, even during a period of flood. This question was very carefully considered in dealing with the main drainage of the Metropolis.

To reduce the amount of pumping to a minimum, it is desirable so to arrange the levels of the sewers as that as much as possible of the sewage shall pass away by gravitation. If the area to be drained were either a uniform level standing a definite height above the river or sea into which it is intended to discharge the sewage, or stood upon a regular slope down to the point of discharge, no pumping would be needed; but when the ground is uneven, and some of it lies lower even than the level of the outfall, it will become necessary to pump the drainage from the lower levels into the higher, from which alone the discharge can be effected. How best to arrange these levels is a question of the highest moment in planning out the positions of the sewers.

The uneven nature of the ground occupied by the Metropolis necessitated three different lines of sewers, each occupying a different level. These, known as the High, Middle, and Low level sewers, are thus arranged:—Upon the north side of the Thames the three lines converge and unite at Abbey Mills, near Bow, where the contents of the Low Level are pumped into the Upper Level sewer, and the aggregate stream carried across the marshes to Barking Creek, through the northern outfall, and there discharged into the river at the period of high water. The theory involved in this arrangement is, that as the flow of water towards the sea consists, during the period of ebb tide, of the land water *plus* the tidal water, the period of *ebb* tide is longer than the period of *flow;* hence any object free to move up and down the channel of the river by the action of the tide, will be carried nearer and nearer the sea at each successive tide. Such occurs with the sewage. It is retained in an immense reservoir near the outfall, until the period of high water, and then discharged during a certain time, the time at which the discharge is stopped being regulated by the state of the tide: the reservoir being arranged to contain an accumulation of eleven hours' sewage. The great object is that the sewage, after its discharge into the river, shall never be brought back by the action of the tide to the Metropolis, and this is entirely effected by placing the outfalls from twelve to thirteen and a-half miles by river below London Bridge.

The section of the sewers is for the most part circular, as combining the greatest strength and capacity with the least cost of labour and material.

The smaller and subsidiary branches are egg-shaped, in order to obtain the greatest *scour* with a minimum amount of flow. This shape was adopted by the Romans in the Cloaca Maxima, which drains the whole of Rome as well as the Campagna. This culvert is fourteen feet wide and thirty-two feet high, and its area is nearly sufficient to drain the whole of the metropolitan district. Its section manifests a considerable knowledge of the power of deep water for scouring the bottom of a sewer, and thus removing the deposits.

The metropolitan culverts are for the most part constructed of brickwork set in cement. Their area varies from four feet diameter to nine feet six inches by twelve feet. The thickness of the brickwork also varies from nine to twenty-seven inches.

The necessity for maintaining a nearly uniform gradient in the lines of sewers, and more particularly the necessity of making the gradient *always in one direction*, compelled them to be carried over or under every obstacle. As an instance of this, we may state that the Middle Level sewer, on the north side of the river, is carried over the Metropolitan Railway near Farringdon Street by a wrought-iron aqueduct of 150 feet span; its weight being 240 tons.

A similar system of drainage is carried out on the south side of the river, the convergence of the three levels being at Deptford Creek, where also is situated the pumping-engine for raising the sewage from the Low Level to the High Level sewer, a height of eighteen feet. The southern outfall passes thence to Crossness, about one and a-half miles further down the river than Barking Creek.

We append a summary of the principal points of engineering interest in this great work. The total cost of the main drainage works is estimated to reach a total of £4,100,000, a sum raised

by loan, and paid off by a 3*d.* rate levied on the Metropolis, producing £180,262 per annum. It will have taken forty years to pay off both principal and interest.

There are 1,300 miles of sewers in London, and eighty-two miles of main sewers; 318,000,000 bricks, and 880,000 cubic yards of concrete have been consumed; and 3,500,000 cubic yards of earth have been removed in the progress of the work. The total pumping power employed is 2,380 horse-power nominal, and the annual consumption of coal is about 20,000 tons.

The sewage on the north side of the Thames is over 10,000,000 cubic feet per day, and over 5,000;000 on the south side. In addition to this, provision is made for 28,500,000 cubic feet of rainfall per day on the north side, and 17,250,000 on the south side; the total being equivalent to a lake fifteen times as large as the Serpentine. The reservoir at Barking is 16¾ feet deep, and covers an area of about 9½ acres; that at Crossness, with an equal depth, has an area of 6½ acres.

The importance of this great engineering work cannot be overrated. It has totally changed the sanitary condition of large areas of the Metropolis; and has effected an improvement in a sanitary point of view of which the cost of the undertaking affords no criterion.

We have entered somewhat largely into the details of this work, as it forms the best example of that system of drainage which aims at conveying away bodily the refuse matter.

II. Many persons are of opinion that to convey away and discharge into a river so enormous a quantity of sewage is a twofold evil: it poisons the water, and wastes a valuable fertilising agent. Those who hold this opinion differ, however, as to the manner in which they would treat the sewage. In some instances, as at Croydon, the sewage is applied to the entire level surface, irrigating the plants or grass at once. In other cases, as at Romford, the ground is intersected by numerous shallow trenches, into which the sewage is pumped, the plants being embedded in the soil adjoining the trenches. The sewage thus passes to the roots through the medium of the soil. The whole district thus irrigated is itself drained, and the effluent water pumped back into the trenches. There can be no question as to the value of sewage for agricultural purposes. The sewage of London is estimated as worth £1,500,000 annually. Its value, as shown at South Norwood, is such, that over fifty tons of Italian rye-grass have been grown to the acre in each year, worth from £30 to £40. This grass has been produced from six successive crops in the twelve months, and the aggregate length of the blades is equal to fifteen feet. At the same time it is asserted that the sewage, after being thus utilised, is actually as pure as the water supplied by some of the Metropolitan water companies, in the proportion of organic matter per gallon.

III. There is another system adopted, which may be mentioned. Leamington and Hastings are the chief localities where this system has been carried out. It is known as the "A B C" process. Under this system the sewage is first deodorised and precipitated, the effluent water being allowed to pass away into the sea or river, the solid residuum being utilised as manure.

The "A B C" is a patented process, and obtains its name from the initial letters of the three principal ingredients used in the process of defecation, *alum, blood,* and *clay*. Other substances are employed: for instance, the sulphate or carbonate of magnesia, manganate of potash, chloride of sodium, animal and vegetable charcoal. A mixture in certain proportions of these substances is added to the sewage so long as precipitation takes place; the average quantity required being 4 pounds of mixture to 1,000 gallons of sewage. The partially dried precipitate has a small quantity of s[illegible]huric acid added to it to fix the ammonia, and it is then regarded by the patentees as a valuable manure.

MINERAL COMMERCIAL PRODUCTS.—VI.

SILICIOUS SUBSTANCES (*continued*).

SERPENTINE, so called from the supposed resemblance of the mineral to the skin of a serpent, is a silicate of magnesia with adventitious admixtures of lime, alumina, iron, chromium, etc., and occurs as a rock or in association with other minerals constituting rock masses. The west of Mayo and Galway are remarkable for their serpentine rocks, which afford the beautiful variegated green and white varieties worked into pilasters, columns, etc. Serpentines and serpentine limestones of great beauty and excellent quality are also quarried in different parts of the county of Cornwall, the Shetland Isles, Canada, the United States, Italy, etc.

Basaltic and kindred rocks—greenstone, whinstone, and trap —are intrusive rocks, for the most part felspathic. Some of these are well adapted for building, but their great use is for paving and macadamising roads, for which purposes they are unrivalled. The columnar structure of basalt is in some places taken advantage of for the construction of stone posts and window-sills. These rocks are abundant in many parts of Scotland, and occur also in Ireland, various districts of Germany, and Nova Scotia.

Lava, a volcanic production, is often similar to trap, and equally useful. It occurs in recent and extinct volcanic districts. *Obsidian*, a volcanic glass, usually black, and somewhat resembling the slag of a glass furnace, is found in Mexico, Central America, Peru, Iceland, etc. *Pumice-stone*, a well-known porous and extremely light stone, used for polishing, etc., and *Pozzuolano* and *trass*, silicious earths much used to mix with limes for hydraulic cements, are also volcanic productions, of which the chief mineral ingredients are augite and felspar. Pumice-stone is quarried in the small islands that lie off the coast of Sicily. Pozzuolano and trass are obtained from Italy, and from many districts of France, Germany, and Scotland.

CLAYS AND ALLIED SUBSTANCES.

Clays, which are silicates of alumina more or less pure, occur in all formations from the firmest slates of the older rocks, and the loose shales of the Carboniferous and the Secondary, to the plastic clays of the Tertiary and the alluvial deposits. They enter largely into the materials and processes of building, as slates, tiles (both for roofing, paving, and ornamental purposes), and bricks; into the manufacture of pottery and earthenware of all sorts, terra-cotta, and many other useful applications.

Common clay, so abundantly diffused over the earth's surface, and chiefly distinguished into three varieties—yellow, brown, and blue—furnishes material for the builder and the maker of the common pottery wares. China and porcelain are made from the fine clays called *kaolin* and *petuntse*, which are almost pure, and are due to the decomposition of the felspars of granitic rocks, the felspar containing soda being especially liable to disintegration. These clays are found in Cornwall, Devon, France, Belgium, and Germany, but can also be artificially prepared. *Pipe-clay* is a white, pure variety, with an excess of silica. It is obtained from Poole and Purbeck. *Fire* or refractory clays, used in the manufacture of fire-bricks, retorts, and crucibles, contain a preponderance of silica over alumina, and occur chiefly in the Carboniferous strata. In England the Stourbridge clay is famous for these purposes. Belgium, and Siegburg in Germany, also furnish fine clays. Others, however, sufficiently pure, can be made available to some extent by the addition of silicious sand. *Fuller's earth* is a very useful clayey substance, having in its composition a large proportion of silica and a quantity of water. It is employed in the preparation of wool, and is abundantly met with in Surrey, Buckingham, Hampshire, Gloucestershire, and Bedford. The *ochres*, chiefly red and yellow, are mixtures of clay and oxides of iron. They are used in the manufacture of colours; the most suitable for this purpose being obtained near Oxford, in Fife, in Antrim, Italy, and other places.

Slates, from their natural cleavage and their great durability, are of extreme utility for a variety of purposes, chiefly roofing, the construction of cisterns, and the manufacture of school slates and pencils. The best are those which are hardest and finest in grain. Besides the common colour, there are green, purple, and grey slates. The laminæ are of different thicknesses, and are used accordingly. Slates are quarried chiefly from rocks of ancient date (Silurian and Cambrian), and are abundantly supplied from Penrhyn, Llanberis, Festiniog, and other parts of Wales, as well as from Cornwall, Devonshire, Westmoreland, Scotland, Ireland, France, Belgium, Germany and Asia.

Hone stones, of which there are many varieties, are slaty stones which are used in straight pieces for sharpening tools after they have been ground on grindstones. The most important varieties are the following:—Norway ragstone, the coarsest variety, imported in large quantities from Norway; Charnwood Forest stone, one of the best substitutes for the Turkey oil-stone, much in request by joiners and others, and obtained from Charnwood Forest, Leicestershire; Turkey oil-stone, of which there are two varieties, white and black, the latter being the harder, surpassing every other oil-stone, used by the engraver, and obtained from the interior of Asia Minor; Ayr stone; snake stone; Scotch stone, used especially for polishing copperplate; Welsh oil-stone, second only to the Charnwood Forest stone, and obtained at Llyn Idwall, near Snowdon, whence is also obtained the "cutler's green stone;" and the German razor hone, derived from a yellow band in the blue slates of the neighbourhood of Ratisbon.

EARTHS OF SODIUM, POTASSIUM, BORON, SULPHUR, ETC.

The elements of the combination of which we are about to speak do not, for the most part, occur naturally in their simple state, but their compounds, especially those of sodium, potassium, and sulphur (which is also native), are numerous, abundant, and valuable.

Common salt (chloride of sodium) is an extremely abundant and quite an indispensable commodity. It exists in sea-water and salt lakes, in the proportion of from 3 to 4 per cent., or even more in some of the lakes, and can be extracted by evaporation. It occurs in a much larger proportion in many brine-springs connected with geological deposits of salt, but these deposits themselves form now by far the best sources of supply. Rock-salt is obtained in England principally from the mines of Cheshire, and also near Belfast; culinary salt is manufactured in large quantities in Cheshire and Worcestershire from brine springs; in both cases, the salt is derived from the Keuper marls of the New Red Sandstone system, in which it occurs in basin-shaped deposits, and is arranged in wedge-shaped masses. Salt-beds occur in rocks of various ages; those of Nova Scotia in the Carboniferous system; the rock-salt of Ireland, England, and Prussian Saxony in the Keuper formation; that of the Carpathian Alps in the Upper Oolite; that of Poland and the Pyrenees in the Cretaceous series; and that of Pisa and Cuba in the Miocene rocks. Beds of salt occur also in China, and many districts of North America. Some of the salt mines of Europe furnish perhaps the most stupendous examples of mining industry. Salt for domestic purposes is refined from the more or less impure native product, and from it also common soda (carbonate of soda)—formerly made, like barilla, from the ashes of sea-weeds, etc.—is manufactured on an immense scale. Chlorine for bleaching and disinfecting purposes is also very largely supplied from the same source. Many parts of the earth being deficient in the supply of salt, it is an important article of commerce. We exported in 1880, 1,051,240 tons; in 1881, 1,006,230 tons; and in 1886, 804,807 tons, valued at £587,962.

The *Alums*, already alluded to under the head of *Aluminum*, are important compounds of sulphate of alumina with sulphate of potash, or soda, or ammonia, potash being the most common. Alum occurs native to a small extent, but from its great value in the arts, especially in dyeing and calico printing, it is manufactured on a large scale. One process is to treat clay with sulphuric acid, by which a sulphate of alumina is formed, to which potash, soda, or ammonia is added, and the resulting crystallised salt is accordingly either a potash, soda, or ammonia alum. Alum is also made from *alum slate* or *shale;* this substance contains alumina, protoxide of iron, a trace of potash, and iron pyrites dispersed through it. This pyritous shale, on exposure to the atmosphere, undergoes decomposition, which is accelerated by the manufacturer, who, availing himself of the carbonaceous character of the shale, applies fire to the alum shale heap. The iron pyrites is changed into sulphate of iron, which forms, with the alumina, a double sulphate of iron and alumina; this is subsequently purified by evaporation, and by the addition of potash the salt is rendered crystallisable. Glasgow, Whitby, and Newcastle are the chief localities of alum manufacture in this country. The best alums are those prepared in Asia Minor and Italy. China produces a considerable quantity, and Tuscany thousands of tons per annum.

TECHNICAL DRAWING.—VIII.

WOODEN BRIDGES (*continued.*)

THE structural portions of the bridge having been completed, the hand-rail may now be commenced.

Having drawn the top rail and the standards which divide the length into ten equal rectangles, draw diagonals in each; then the lines forming the cross-struts are to be drawn parallel to these. The longitudinal and transverse sections will not, it is presumed, require further instruction, and we can therefore turn our attention to the next series of examples of hand-rails.

The most simple of these is Fig. 43. In beginning this it is best to draw the section (Fig. 44) first, as from it the elevation of the cornice and of the horizontal bars must be projected.

Having, then, drawn Fig. 44, draw horizontals from the different points in the section of the cornice, *a*, and from the top and bottom of the section of the top rail, *b*.

Next draw the standards, *c c;* then from the angles of the square middle rail, *d*, project the elevation, *d*, which will complete the figure.

Fig. 45 is an enlarged elevation of the hand-rail already shown in Fig. 40. Here the section (Fig. 46) is to be drawn first, excepting the part *d d*, which is determined according to the angle at which the struts cross each other. Having, then, projected the elevation of the top rail and cornice from the section, draw the standards, *c c*, and diagonals in the rectangle.

Now let us suppose (as would in practice, of course, be the case) that the struts are to be of a definite width. To set this off accurately, draw a line through each diagonal, at any part, but at *right angles* to it. On these, on each side of the diagonals, set off from the intersection half of the width of the struts; then lines drawn through these points parallel to the diagonals will give the sides of the cross-pieces required.

It will be seen that the lines thus drawn will at their intersection form a lozenge or diamond-shape; from the lower and upper angle of this figure draw horizontals, which will give the section, *d d*, in Fig. 46, and in this the central vertical line will show that the struts in crossing are "halved" into each other, so they are "flush" with the uprights and with the upper rail. The splaying of the edges can, of course, be done without any further guidance.

Fig. 47 is a hand-rail of a similar character to the last, but the space between the standards is to be filled with two pairs of struts at right angles to each other. Now the space is doubly as long as it is wide; therefore divide it into two equal squares, in which draw diagonals. On these, set off from their intersection half of the width of the struts, and draw the lines which form the edges of them; the section (Fig. 48) can then, as in the last figure, be completed from the elevation.

Fig. 50 is a mere trellis-rail, and will be found very easy to draw; but care is required so that all the interstices may be *equal squares.*

Having drawn the section (Fig. 49), and projected the cornice and upper rail in the elevation (Fig. 50), draw centre-lines for each of the cross-pieces, which will be readily accomplished by means of your set-square of 45°. On each side of the intersection set off half the width of the pieces, and draw the lines; it will thus be seen that this is a repetition of the last figure, but with a multiplication of parts.

We still continue using wooden bridges as examples for drawing, not because they are as much used in this country as they were in times gone by, but because the principles of their construction convey so much instruction, which will be of service in the subsequent section on "Roofs." And further, in these days of railways and emigration, some knowledge of the construction of bridges of a material which is so generally available cannot fail to be of service.

Fig. 51 is partly an elevation and partly a longitudinal section of a covered wooden truss-bridge, such as is frequently used for passengers to pass from one platform of a railway to the other.

Here it is necessary briefly to remind the student of the action of a *king-post*, viz., that when the lower ends of the principal rafters (two strong timbers, *which together* are longer than the space to be bridged over) are mortised or otherwise fixed by their lower ends to the tie-beam, the upper ends abutting against the head of the king-post, this acts as the key-stone of an arch, and being lengthened, the tie-beam is bolted or strapped up to it. This principle, illustrated by the necessary

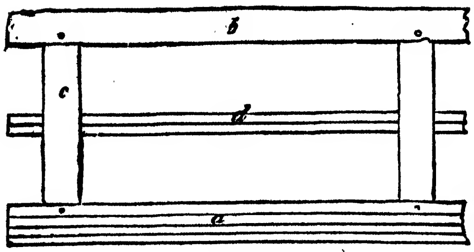


Fig. 43.

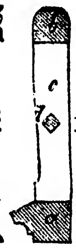


Fig. 44.

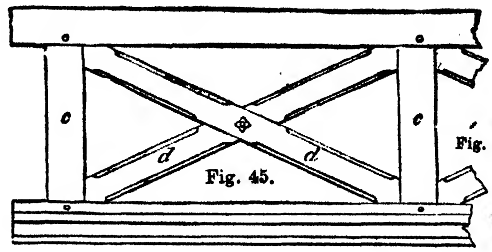


Fig. 45.

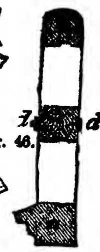


Fig. 46.

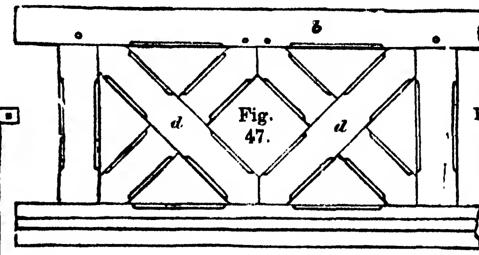


Fig. 47.

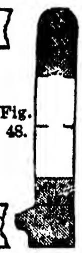


Fig. 48.

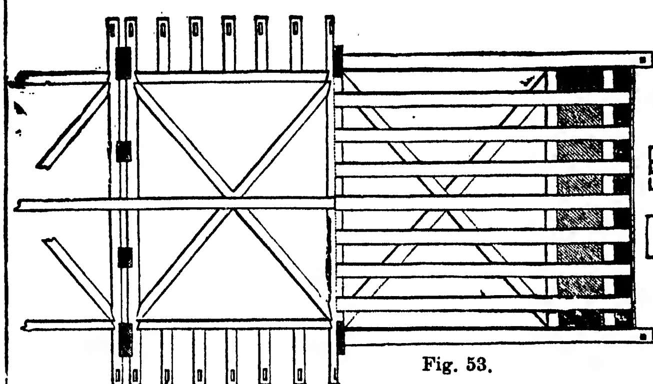


Fig. 53.

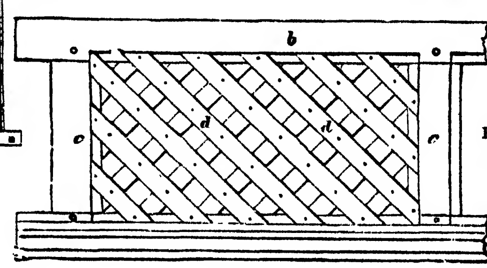


Fig. 50.

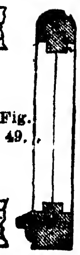


Fig. 49.

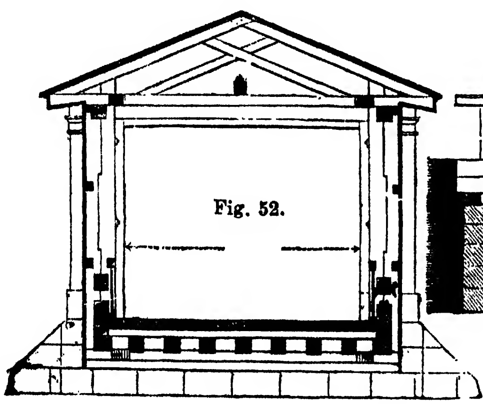


Fig. 52.

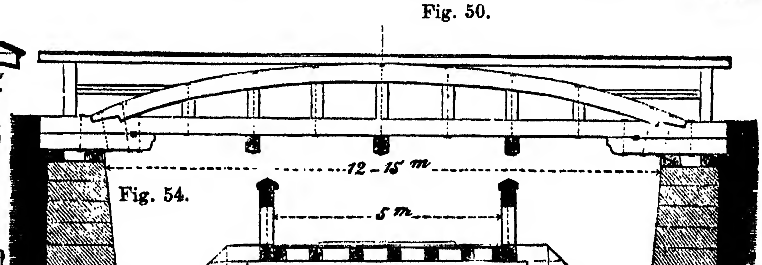


Fig. 54.

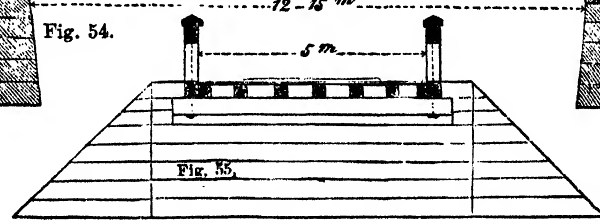


Fig. 55.

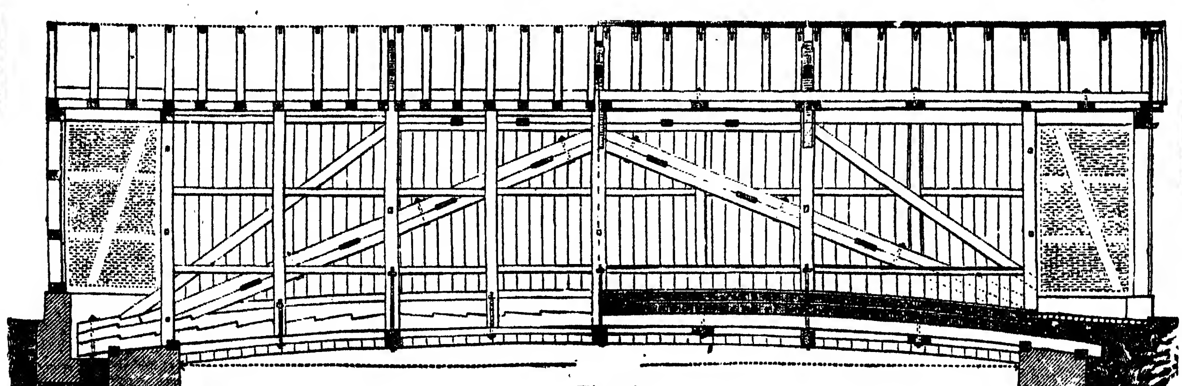


Fig. 51.

diagrams, is treated of in "Building Construction," and will be further worked out in connection with roofs.

In the present example the tie-beam is built up of two equal timbers, which are scarfed or toothed into each other, and the king-post, being also double, clasps the tie-beam at the bottom. Underneath the tie-beam a transverse bearer passes from one king-post to the other, and these being screwed up by means of screw-bolts, the tie-beam is drawn up into a curve. The principals, too, are made up of two equal lengths.

In addition to this there are queen-posts, which are supported at the top by means of a collar-beam and struts; and to these, bearers passing transversely under the tie-beams are bolted, like those under the king-posts. There are also intermediate suspending posts, from which bearers are not suspended, but to which bolts pass through the tie-beams.

The half of Fig. 51, which is given in section, will show the manner in which the planks forming the floor of the bridge are laid, and the longitudinal girders resting on the transverse bearers are shown in the section (Fig. 52), in which the simple roof timbers are also shown.

Fig. 53 is a horizontal section, showing the diagonal straining-pieces between the bearers.

A few instructions on the method of drawing this subject (Fig. 51) will now be given.

First draw the piers, and a straight line uniting their springing points.

Bisect this line, and in the perpendicular set off from the intersection the height of the curve from the horizontal line. There will then be three fixed points—viz., the two springing points, and that in the perpendicular.

Now it will be remembered that if these points be joined, and the lines uniting them be bisected, the intersection of the bisecting lines will be the centre of the circle of which the arc is a part. (See Fig. 10, "Practical Geometry.")

Having, then, thus found the centre, describe the arc forming the under side of the tie-beam. The arcs under this are to be drawn with the same radius, moving the centres a little lower down on the perpendicular.

The tie-beam is rather broader in the middle than at the ends, and therefore the upper arc must be struck with a rather shorter radius, the centre being slightly higher than that from which the under side was drawn; from a point half-way between these two centres an arc must be struck, exactly between the upper and lower edges of the tie-beam, and on this the toothing of the scarf is to be drawn.

Now proceed to draw the king-post, measuring half its width on each side of the central perpendicular, then the principal rafters, the collar-beam, and the longitudinal joist above it; then follow the queen-posts, the suspension-pieces, and the ends of the bearers.

The foundation for the fronts, and the fronts themselves, are now to be drawn; then the ridge and the rafters.

After this the boarding of the sides of the bridge is to be filled in, and any other detail which may not have required separate mention.

Figs. 52 and 53 are too simple in their lines for the student to need any instructions as to the mode of drawing them; he is simply advised to draw the different parts in the order in which they have been explained in the elevation.

Fig. 54 is a side elevation of a small bridge constructed on the "bow suspension truss" principle.

Here the bow, consisting of a single beam, is mortised into the ends of the tie-beam, which are in their turn strengthened by saddle-pieces, bolts passing through these saddle-pieces, the tie-beam, and the bow.

At regular intervals perpendicular posts are placed between the tie-beam and the bow.

Underneath these are placed the transverse bearers, bolts passing through these, the tie-beam, the perpendiculars, and bow. On the bearers timbers are laid parallel to the truss, and on these the flooring of the bridge rests. This arrangement will be clearly understood on referring to the section (Fig. 55).

In commencing to copy this example, draw the horizontal line which forms the tops of the abutments, and then add the oblique lines representing the imposts.

Next draw another horizontal line, and between this and the last mark off the widths of the ends of the cross-timbers which act as wall-plates, on which the trusses are to rest.

This horizontal will also give the lower side of the saddle-pieces, and the horizontal which will give the top of these will also form the under side of the tie-beam, the upper side of which, and the ends of the saddle-pieces, may now be drawn.

The points at which the outer arc of the bow meets the upper line of the tie-beam are next to be marked, and the height of the bow set off on a central perpendicular. From these three points, the centre from which the arc is struck will be found in the manner already mentioned. The internal arc and the mortises at the ends will then complete the bow.

Having divided the space on each side into four equal parts by dotted perpendiculars, set off on each side of these half the thickness of the uprights, draw the ends of the bearers, the rail-bolts, etc.

The section is so very simple, that no further instruction connected with its delineation is deemed necessary.

It can be well understood that the system of forming the bow of a single timber must be limited to bridges of small span, and an improvement was effected in this respect by the introduction of a system invented by Philibert de Lorme, a celebrated French architect.

This system was not new, its author having proposed it in the sixteenth century, and it had been used more or less from that period; but it seems to have been first applied to bridges in that over the Weser, near Minden, in Westphalia, in the year 1800.

The De Lorme system will be fully described and illustrated in connection with "Roofs," in the construction of which it has been principally used; it may, however, be briefly stated here that it consists in building up the bow of separate pieces of timber placed *edge-wise*, and united in the manner called break-joint—that is, the joints in the pieces of each layer of timber composing the bow are alternated, so that those in the one are over the whole part of the other, nails and bolts passing through the complete thickness.

ELECTRICAL ENGINEERING.—V.

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INFLUENCE—THE ELECTROPHORUS—WIMSHURST MACHINE—THE ELECTRIC SPARK.

It has been seen that an electrified body exerts some influence over other bodies placed near it, as in the case of the pith-ball being attracted to the glass rod. In order that this attraction should exist, some change in the distribution of the electricity in the attracted body must have taken place. The nature of this change can be seen from the following experiment. Bring any conducting body near the positively-charged plate of an electrical machine, and examine how the electrification is now distributed over its surface. This can be best done by means of a

Fig. 4.—PROOF-PLANE.

proof-plane and a gold-leaf electroscope. A proof-plane (Fig. 4) consists of a small light metallic disc, M, fixed on the end of a glass rod, H. Taking hold of the end of this rod, touch the different portions of the conducting body with the disc, which will then receive a charge similar to that at the point touched; now bring this charged disc into contact with the knob of the electroscope, when the divergence of the leaves will give a rough measure of the strength of electrification at that point. A thorough examination of the different points of the body shows that the end which is nearest the machine is strongly negative, the most distant point is equally strongly positive, while at the centre there appears to be no electrification whatever. This phenomenon is known as *induction* or *influence*. Without entering into any question as to the nature of electricity, it can be said that a non-electrified body may be looked upon as containing exactly equal quantities of

positive and negative electricity; when it contains an excess of one kind over the other, it is then said to be electrified with that kind which is in excess. The earth is a kind of enormous reservoir containing equal amounts of the opposite kinds, and can therefore be considered a standard for non-electrified bodies. Returning to our experiment, the positively-electrified glass plate attracted the negative electricity in the conducting body, and repelled the positive to the farthest point possible. If while in this condition the body had been connected to the earth by a wire capable of conducting electricity, it is clear that the positive charge would have been repelled to earth, and if the connecting wire were now broken the conducting body would have been left negatively electrified. A conducting body can thus be electrified by *induction* or *influence* without having been subjected to friction, and without having been in contact with any electrified body. This principle, upon which all influence machines depend, is best illustrated by the earliest and simplest of them all—the *electrophorus*.

The electrophorus (Fig. 5), due to Volta (1775), consists of

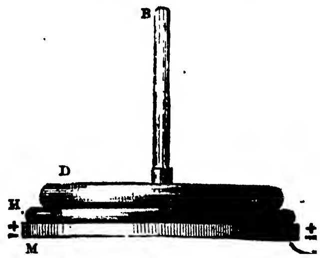

Fig. 5.—THE ELECTROPHORUS.

a flat metallic disc, M, containing or supporting a disc of some non-conducting substance, usually resin or ebonite, H. D is a metal disc, to which the glass handle B is attached. To use the instrument, take hold of the end of the handle and raise the disc D; rub the non-conducting substance with cat's fur, when it will become negatively electrified. Now place the disc D on the electrified body, and the electricities will become by *influence* distributed over the whole apparatus, as indicated by the signs in Fig. 5. The negative charge on H attracts a positive charge on the under surface of D, and repels a negative charge to its upper surface. If this plate be now

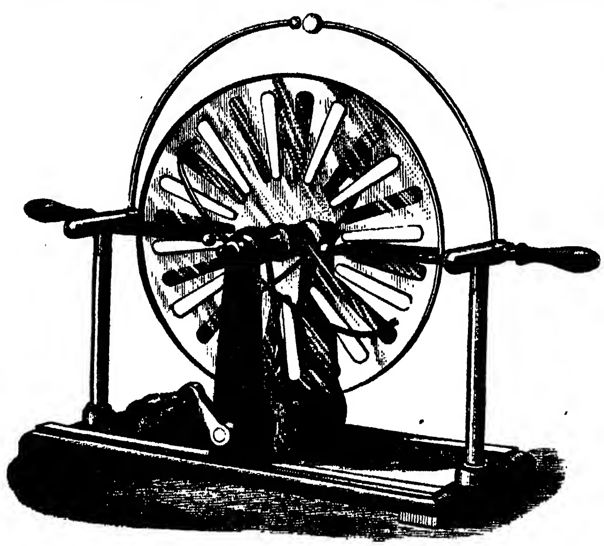

Fig. 6.—THE WIMSHURST MACHINE.

connected to earth by touching it with the finger, the negative electricity will be repelled to earth; and if the disc be now raised it will have a positive charge, which will distribute itself over its surface, while the negative charge on H remains as before. If the disc D had not been joined to earth when on H, but had simply been lifted off, the positive and negative charges on it would have gradually reunited as it was withdrawn from H, and finally would have neutralised one another; the touching of D when under the influence of H is an essential part of the operation. By continuing this operation, an almost unlimited number of charges can be obtained on D without in any way affecting the original charge on H, but these charges are not obtained without a corresponding expenditure of energy. This energy is not expended in the form of friction, but (while raising D) in doing the work necessary to overcome the attraction between D and H when one is charged positively and the other negatively. In doing any of these experiments the greatest care should be taken that every portion of the apparatus meant to be non-conducting be perfectly free from any trace of moisture, and this is most conveniently done by keeping the whole apparatus heated, and occasionally passing portions of it through the flame of a spirit-lamp.

The electrophorus is effective, but the operation is laborious and the charges obtained small. It stands in the same relation to the modern influence machine that the glass rod does to the friction machine. Fig. 6 is an illustration of the Wimshurst machine, which is the best modern type. It consists of two glass discs, well coated with shellac varnish, mounted on loose bosses on the same spindle, and so arranged as to rotate in opposite directions. On these discs are cemented a number of thin brass strips fixed radially at equal distances apart. The plates revolve about an eighth of an inch from one another, and at each end of their horizontal diameter is fixed a kind of metallic comb supported on a glass pillar, which collects the charges generated on the sector-shaped metallic strips. A curved brass bar, with a metal brush at each end, is fixed at an angle of about 45° to the horizontal axis, which connects electrically the opposite pairs of sectors as they pass under it; a similar rod is attached at the back of the machine, the pair being at right angles to one another. The two curved bars above the plates are discharging-rods. As the plates revolve, the sector which is opposite one of the metallic brushes attracts an opposite charge on the sector which is in contact with that brush, and repels an equal charge of the same kind as itself through the curved rod to the sector which that rod touches at the diametrically opposite side of the glass plate. Two sectors on each plate are thus charged at the same instant (by an operation

Fig. 7.—THE ELECTRIC SPARK.

as each passes on it delivers up a portion of this charge to the comb-shaped collectors, but goes on with a sufficient charge to influence another sector in its turn. This is an extremely powerful form of influence machine, sparks several inches long being easily obtained from it.

The electric spark, from whatever source it may come, whether it be in the form of a discharge from an electrical machine, or in the form of lightning due to atmospheric influence, seldom travels for any distance in a straight line (Fig. 7), always following the path of least resistance between the two points, and this line is determined by the particles of conducting matter always present in the atmosphere.

PRINCIPLES OF DESIGN.—III.

By Christopher Dresser, Ph.D., F.L.S., etc.

TRUTH, BEAUTY, AND POWER IN ORNAMENTATION.

In my two previous chapters I have attempted to set forth some of the first principles of ornament, and to call attention to the purport or intention of certain of the leading historic styles, and the manner in which they make utterance to us of the faith or sentiments of their producers.

But there are other utterances of ornament, and other general expressions which decorative forms convey to the mind. Thus sharp, angular, or spiny forms are more or less exciting (Fig. 9); while bold and broad forms are soothing, or tend to give repose.

Sharp or angular forms, where combined in ornament, act upon the senses much as racy and pointed sayings do. Thus "cut" or angular glass, spinose metal-work, as the pointed foliation of some wrought-iron gates, and other works in which there is a prevalence of angles and points, so act upon the mind as to stimulate it, and thus produce an effect opposite to repose; while "breadth" of form and "largeness" of treatment induce tranquillity and meditation.

Nothing can be more important to the ornamentist than the scientific study of art. The metaphysical inquiry into cause and effect, as relating to decorative ideas, is very important—indeed, all-important—to the true decorator. He must constantly ask himself what effect such and such forms have upon the mind—which effects are soothing, which cheerful, which melancholy, which rich, which ethereal, which gorgeous, which solid, which graceful, which lovable, and so on; and in order to do this he must separate the various elements of ornamental composition, and consider these apart, so as to be sure that he is not mistaken as to what affects the mind in any particular manner, and he must then combine those elements in various proportions, and consider the effects of the various combinations on his own mind and that of others, and thus he will discover what will enable him to so act on the senses as to induce effects such as he may desire to produce.

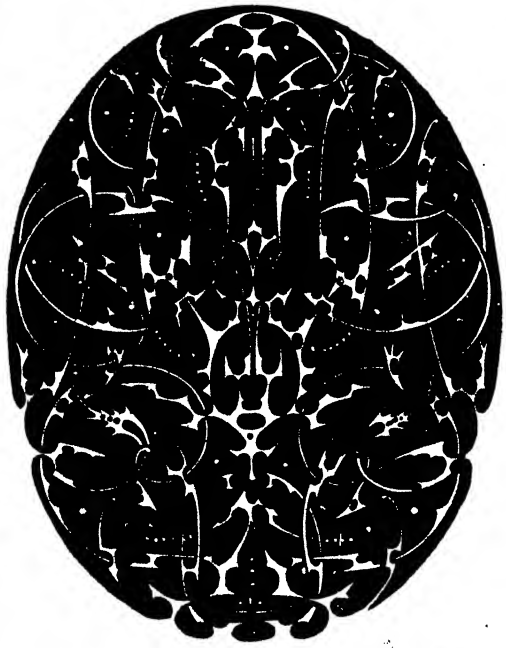

Fig. 9.—Ornament composed of sharp and spiny forms.

Are we to decorate a dining-room, let the decoration give the sense of richness; a drawing-room, let it give cheerfulness; a library, let it give worth; a bedroom, repose; but glitter must never occur in large quantities, for that which excites can only be sparingly indulged in; for if it is too freely employed, it gives the sense of vulgarity.

In this chapter I have to speak primarily of *Truth, Beauty*, and *Power*. Long since I was so fully impressed with the idea that true art-principles are so perfectly manifested in these three words, that I embodied them in an ornamental device which I painted on my study door, so that all who entered might learn the principles which I sought to manifest in my works.

There can be morality or immorality in art, the utterance of truth or of falsehood; and by his art the ornamentist may exalt or debase a nation.

Truth.—How noble, how beautiful, how righteous to utter it; and how debasing is falsehood; yet we see falsehood preferred to truth—that which debases to that which exalts, in art as well as morals; and I fear that there is almost as much that is false, degrading, and untrue in my beautiful art as there is of the noble, righteous, and exalting, although art should only be practised by ennobling hands. It is this grovelling art, this so-called ornamentation, which tends to debase rather than exalt, to degrade rather than make noble, to foster a lie rather than utter truth, which brings about the abasement of our calling, and causes our art to fail in many instances in laying hold of, and clinging to, the affections of the noble and the great. Ornamentation is in the highest sense of the word a Fine Art; there is no art more noble, none more exalted. It can cheer the sorrowing; it can soothe the troubled; it can enhance the joys of those who make merry; it can inculcate the doctrine of truth; it can refine, elevate, purify, and point onward and upward to heaven and to God. It is a fine art, for it embodies and expresses the feelings of the soul of man—that inward spirit which was breathed by the Creator into the lifeless clay as the image of His life, however noble, pure, or holy.

This being the case, those who ignore decoration cast aside a source of refinement, and deprive themselves of what may induce their elevation in virtue and morals. Such a neglect on the part of those who can afford luxuries would be highly censurable were it not that the professors of the art are for the most part false pretenders, knowing not what they practise, and men ignorant of the powers which they hold in their hands. The true artist is a rare creature; he is often unknown, frequently misunderstood, or not understood at all, and is not unfrequently lost to a people that prefer shallowness to deep meaning, falsehood to truth, and glitter to repose.

We now see the utter folly of appealing simply to what is called "taste" in matters of art, and the uselessness of yielding to the caprice (falsely called taste) of the uneducated in such matters, especially as this so-called taste is often of the most vulgar and debased order. We also see the absurdity of persons who employ a true artist interfering with his judgment and ideas. The true artist is a noble teacher; shall he be told, then, what morals he shall inculcate, and what lofty truths he shall embody in his works, or omit from them? Do we tell the preacher what he shall say, and ask him to withhold whatever is refining and elevating? We do not, and in art we must leave the professors free to teach, and hold them responsible for their teachings.

If I thought that I had now convinced my reader that decorative art does not consist in the placing together forms merely, however beautiful they may be individually or collectively; nor in rendering objects simply what is called pretty; but that it is a power for good or evil; that it is what will elevate or debase—that which cannot be neutral in its tendency—I would advance to consider its principles; but I cannot teach, nor can I be understood, unless the reader *feels* that he who practises art wields a vast power, for the rightful use of which he must be held responsible.

All graining of wood is false, inasmuch as it attempts to deceive, the effort being made at causing one material to look like another which it is not. All "marbling" is false also: a floor-cloth made in imitation of carpet or matting is false; a Brussels carpet that imitates a Turkey carpet is false; so is a jug that imitates wicker-work, a printed fabric that imitates one which is woven, a gas-lamp that imitates an oil-lamp. These are all untruths in expression, and are, besides, vulgar absurdities which are the more lamentable, as the imitation is always less beautiful than the thing imitated; and as each material has the power of expressing beauty truthfully, thus truth has its own reward. A deal door is beautiful, but it will not keep clean; let it then be varnished. It is now preserved, and its own characteristic features are enhanced by the varnish, so that its individuality is emphasised, and no untruth is told. A floor-cloth can present a pattern with true and beautiful curves—how absurd, then, to try and imitate the dotty effect of a carpet; and the Brussels carpet can express truer curves than the Turkey carpet, then why imitate the latter? But perhaps the most senseless of all these absurdities is the

making an earthen jug in imitation of wicker-work, when if so formed it would be useless as a water-vessel. I can imagine a fool in his simplicity priding himself on such a bright thought as the production of a vessel of this kind, but I cannot imagine any rightly constituted mind producing or commending such an idea. Let the expression of our art ever be truthful.

Beauty. — I will say little on this head, for decorative forms must be beautiful. Shapes which are not beautiful are rarely decorative. I will not now attempt to express what character forms should have in order that they be considered beautiful, but will content myself by saying that they must be truthful in expression, and graceful, delicate, and refined in contour, manifesting no coarseness, vulgarity, or obtrusiveness of character. My views of the beautiful must be gathered from the series of articles which will follow, but this I may here say, that the beautiful manifests no want, no shortcoming. A composition that is beautiful must have no parts which can be taken from it and yet leave the remainder equally good or better. The perfectly beautiful is that which admits of no improvement. The beautiful is lovable, and, as that which is lovable, takes hold of the affections and clings to them, binding itself firmer and firmer to them as time rolls on. If an object is really beautiful we do not tire of it; fashion does not induce us to change it; the merely new does not displace it. It becomes as an old friend, more loved as its good qualities are better understood.

Power.—We now come to consider an art-element or principle of great importance, for if absent from any composition, feebleness or weakness is the result, the manifestation of which is not pleasant. Weakness is childish, it is infantine; power is manly—power is God-like. With what power do the plants burst from the earth in spring! With what power do the buds develop into branches! The powerful orator is a man to be admired, the powerful thinker a man we esteem. Even the simple power, or brute-force, of animals we involuntarily approve—the powerful tiger and the powerful horse call forth our commendation, for power is antagonistic to weakness. Power also manifests earnestness; power means energy; power implies a conqueror. Our compositions, then, must be powerful.

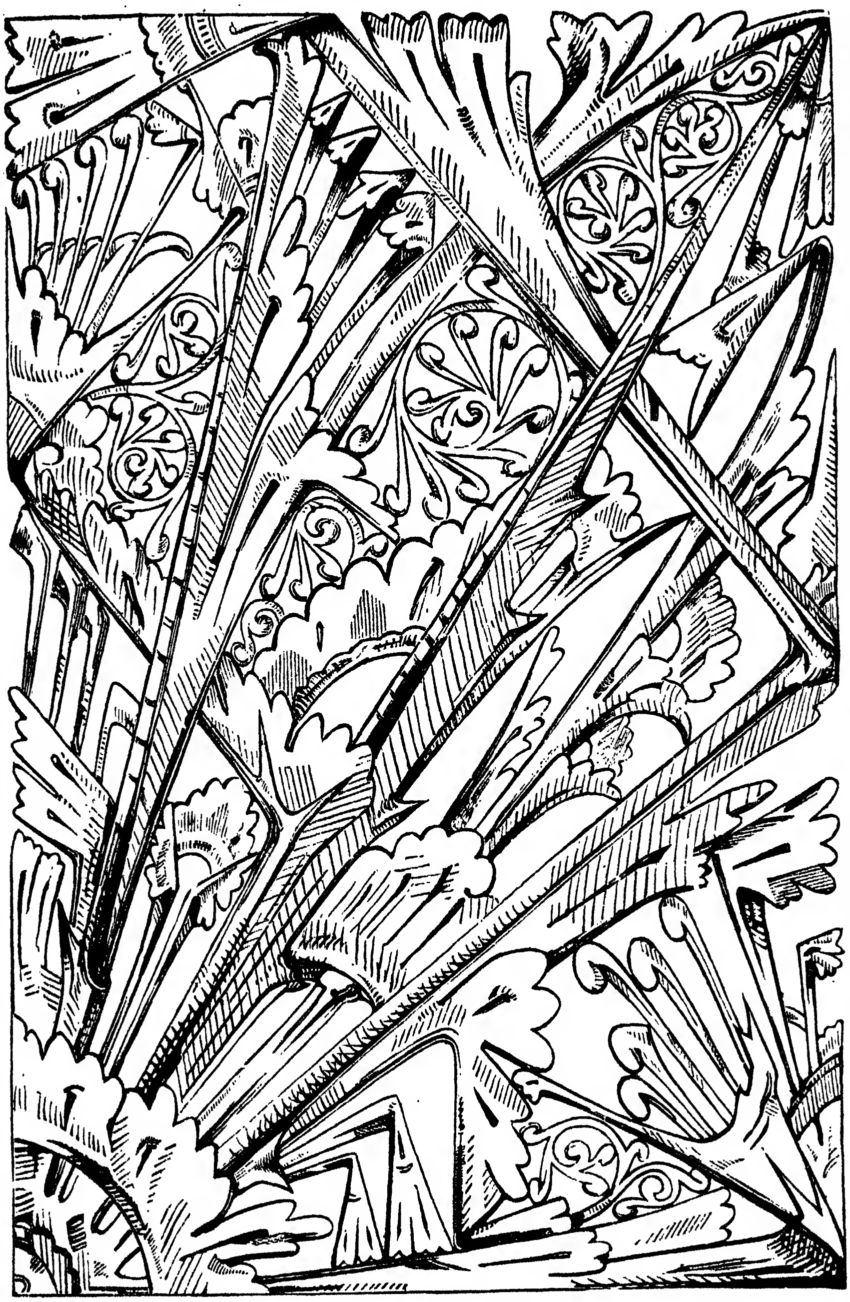

Fig. 10.—DESIGN EXEMPLIFYING POWER.

But besides all this, we, the professors of decorative art, must manifest power in our works, for we are teachers sent forth to instruct, and ennoble, and elevate our fellow-creatures. We shall not be believed if we do not utter our truths with power; let truth, then, be uttered with power, and in the form of beauty.

I have given in this chapter an original sketch (Fig. 10), in which I have sought to embody chiefly the one idea of power, energy, force, or vigour, as a dominant idea; and in order to do this, I have employed such lines as we see in the bursting buds of spring, when the energy of growth is at its maximum, and especially such as are to be seen in the spring growth of a luxuriant tropical vegetation; and I have also availed myself of those forms which we see in certain bones of birds which are associated with the organs of flight, and which give us an impression of great power, as well as those which we observe in the powerful propelling fins of certain species of fish.

VEGETABLE COMMERCIAL PRODUCTS.—IV.

PLANTS YIELDING SPICES AND CONDIMENTS (*continued*).

CARDAMOMS (*Elettaria cardamomum*, Maton; natural order, *Zingiberaceæ*).—Cardamom seeds are obtained from several other allied plants, but those of the above species of *Elettaria* constitute the true officinal Malabar cardamoms.

The cardamom is an obtusely triangular three-celled pod, about half an inch in length, of a pale-straw colour, and furrowed longitudinally on its outer surface. This pod contains numerous reddish-brown, rugose seeds, about the size of mustard seeds, internally white, and having a pleasant aromatic odour and an agreeable taste.

Cardamoms are principally employed here in medicine as a flavouring ingredient, and occasionally as a stimulant and carminative, especially in the form of a simple or compound tincture. In India they are much used as a favourite condiment for various kinds of food, as curries, ketchups, and soups. Their active principle is a pungent volatile oil.

Cardamoms are shipped to Britain from Ceylon, the Malay peninsula, Sumatra, Java, Siam, Cochin-China, and the Malabar coast. The quantity of all kinds imported is about twenty-five tons per annum.

UMBELLIFEROUS PLANTS WITH AROMATIC FRUITS.

There are a few seeds which, from their pungent aromatic flavour, are used as condiments, and may very properly be classed with the spices.

The fruits of the caraway, coriander, and anise—called in commerce seeds—although cultivated in England, are imported somewhat largely from the Continent, and are therefore deserving of notice.

CARAWAY (*Carum carui*, L.).—The caraway is indigenous to most parts of Europe, as well as to England. It is cultivated to some extent in Essex and Kent. The taste of the seeds is aromatic and warm, and their odour is fragrant, but peculiar. The seeds are much used by the confectioner, and are sometimes added to bread; coated with sugar, they form the well-known "caraway comfits" to which children are so partial. We import about 500 tons of caraway seeds annually from Germany and Holland, nearly the whole of which are retained for home consumption.

CORIANDER (*Coriandrum sativum*, L.).—The fruit of this plant is globose, having a peculiar smell and a pleasant, aromatic taste. In a fresh state both the fruit and foliage have an extremely disagreeable odour; nevertheless, the Tartars are said to use it in the preparation of a favourite soup.

The coriander is indigenous to Southern Europe and Italy, but has a wide geographical range, bearing the climate of India and Britain equally well. It is cultivated in England, particularly in Suffolk and Essex, and is valued both by the apothecary and the distiller. Coriander is used in medicine for its carminative and aromatic properties, as a corrective to the griping qualities of cathartics. It is more used in confectionery than in medicine. Coriander-seed is also employed in adulterating beer. The poor Indian mixes these seeds with his curry, and they are equally welcome at the table of the rich. The imports from Germany to England average fifty tons per annum.

ANISE (*Pimpinella anisum*, L.).—This is a perennial plant, with an erect, round, striated, rough, or downy stem; pinnatisect leaves, white flowers, and an ovate, downy, aromatic fruit, resembling the finer kinds of parsley-seed in shape, and grateful and sweetish to the taste.

The oil of anise is obtained by distillation from the seed, about one cwt. of seed yielding two pounds of the oil. It is used in confectionery and in medicine. Anise is indigenous to Egypt, but is now largely grown in Malta, Spain, Italy, France, Germany, and the East Indies. The principal imports are from Alicante in Spain, and Hamburg in Germany, and average about seventy tons per annum.

Other umbelliferous plants used as condiments are cumin (*Cuminum cymium*, L.) and angelica (*Archangelica officinalis*, Hoffm.).

STAR ANISE (*Illicium anisatum*; natural order, *Magnoliaceæ*).—This plant is so called because the flavour of aniseed pervades the whole of it, especially the fruit; but it is not at all allied to anise, belonging to a totally different natural order. It is a shrub indigenous to China and Japan; its fruit is used to flavour sweetmeats, confectionery, and liquors. The aromatic oil of star anise, singularly enough, in every respect resembles anise oil, for which it is often substituted. In India, star anise is an important article of commerce, and sold in all the bazaars.

MUSTARD.—The seeds of *Sinapis nigra*, L., often mixed with *S. alba* (natural order, *Cruciferæ*).—The spherical seeds of these two species are crushed, pounded, and then sifted through a fine sieve; the fine, powdery product is the "flour of mustard" in common use. The outer skin of the seeds, separated by sifting, forms a coarse powder, which is sold for adulterating pepper. Mustard-seed is largely imported from the East Indies for the expression of oil; and white-mustard seed is imported from Northern Germany, in small quantities, for grinding with the black mustard-seed grown in England.

IV. PLANTS YIELDING SUGAR.

SUGAR-CANE (*Saccharum officinarum*, L.; natural order, *Gramineæ*).—This plant, next to rice and maize, is the most valuable of the tropical grasses. Its stem, which is solid, cylindrical, and jointed, is two inches in diameter, and from twelve to fifteen feet in height; its leaves are long, narrow, and drooping; flowers very handsome, appearing like a plume of white feathers, tinged with lilac. A field of sugar-canes in blossom presents a very beautiful appearance.

The sugar-cane is seldom permitted to flower under cultivation. It is propagated by sections of the culm, or stem, with buds in them. Trenches are cut, and the pieces of the culm are laid horizontally in them; the earth is then thrown into the trench, and the canes soon develop from the nodes or joints of the culm. As they grow up, and the wind gains power over them, the lower leaves are removed, and the stems are strengthened by being fastened to bamboo supports.

The sugar-cane plant is very sensitive to cold, and therefore its cultivation is restricted to the tropics, and to regions on their borders where there is little or no frost. In the Old World sugar plantations are mostly confined to countries lying between the 40th parallel of north latitude and a corresponding degree south; in America, along the Atlantic seaboard, they do not thrive beyond 33° north latitude and 35° south latitude; whilst on the Pacific side the sugar-cane matures about 5° further to the north and south of the equator. The principal countries where sugar is largely grown are the West Indies, Venezuela, Brazil, Mauritius, British India, China, Japan, the Sunda, Philippine, and Sandwich Islands, and the Southern United States of America. Moreton Bay and the northern parts of Australia are admirably suited, both in soil and climate, to sugar culture.

Manufacture of Sugar.—When the cane is ripe, it is cut down, deprived of its top and leaves, cut up into convenient lengths, tied up in bundles, and taken to the mill. Here the canes are crushed between iron rollers, the juice from them flowing into vessels, where it is boiled with the addition of lime, and evaporated to the consistence of syrup, care being taken to remove any scum which appears on the surface during this part of the process. The lime is added to remove any acidity, and prevent fermentation. The material of the fire consists of the refuse crushed cane, dried for that purpose in the sun. Six or eight pounds of cane-juice will yield one pound of raw sugar; and from sixteen to twenty cart-loads of cane ought to make a hogshead of sugar, when thoroughly ripe. The cane syrup thus prepared is transferred to shallow vessels, or coolers, in which it is stirred until it becomes granulated; it is then put into hogsheads having holes in the bottom, which are placed in an upright position over a large cistern, and allowed to drain. In this state it is called muscovado or brown sugar, and the drainings molasses. The casks are then headed down and shipped. This muscovado is purchased by the grocers, and constitutes the brown or moist sugar of the shops.

The planters in the West Indies generally send their sugar to England in the form of muscovado; but in the French, Spanish, and Portuguese settlements, it is usually converted into clayed sugar before exportation. The process is as follows:—The sugar from the coolers is placed in conical pots with holes at the bottom, having their points downward. A quantity of clay is laid on the top and kept moistened with water, which, oozing gently from the clay through the sugar, dilutes the molasses, and causes more of it to come away than in the hogshead, leaving it whiter and purer than the muscovado sugar.

Loaf or refined sugar is made from the muscovado by the sugar-bakers in England. The muscovado is re-boiled, and refined with the serum of bullock's blood or the white of eggs; it is then transferred to conical moulds, and clayed repeatedly until perfectly white. The sugar is then removed from the moulds, and set in a stove to dry.

The sugar-cane, a plant originally confined to Asia, and which grew wild in India, was introduced into the south of Europe from the East by the Saracens, soon after their conquests in the ninth century. In the twelfth century, sugar plantations were established in Cyprus, Rhodes, Candia, Malta, Sicily, and Spain; and as early as the beginning of the fifteenth century they had been extended to Granada, Murcia, Portugal, Madeira, and the Canary Islands.

The sugar-cane is now cultivated at only a few places in Europe, viz., Malta, Sicily, and the south of Spain. The rest of the sugar plantations have disappeared from the countries about the Mediterranean, in consequence of the extent of the great American plantations, and those in the West Indies.

In the middle of the sixteenth century the sugar-cane was transplanted by the Portuguese to Brazil, and by the Spaniards to the West Indies, where the greatest quantity of sugar is now produced. Brazil has now 900 sugar plantations, producing annually about 50,000 tons of sugar; and of the West India Islands, Cuba and Jamaica alone raise 150,000 tons for exportation yearly. Porto-Rico, and the French, Dutch, and Danish colonies in the West Indies, export sugar largely, as do also Louisiana and Alabama, by way of New Orleans. The exports of sugar from Mexico go mostly to New Granada, Caracas, and Ecuador in South America.

The East Indies, Java, Sumatra, the Philippine Islands, Siam, Cochin-China, Bengal, and Ceylon, all produce sugar for exportation. Sugar has been made in China, indeed, from very remote antiquity, and large quantities also have been exported from India in all ages.

In 1886, 16,133,661 cwts. of raw sugar were imported into the United Kingdom, valued at £10,541,149. Only a part of this is retained for home consumption, the remainder—which, however, does not amount to any considerable quantity—being re-exported.

Rum, or Brandy of Sugar.—The best is distilled from the pure juice of sugar; the inferior kind is made from treacle, and from the residuum in the sugar refineries. Jamaica rum is the finest, about three millions of gallons being annually imported into England from the West Indies. Rum is also distilled for exportation in Bengal, Madras, Batavia, and Manilla. The native arrack of India has been nearly driven out of the market by this spirit.

Besides the sugar-cane, many other plants yield sugar. The principal of these are:—

1. Beet-root and Mangold-wurzel (two varieties of *Beta vulgaris*, Tournef; natural order, *Chenopodiaceæ*) are cultivated very extensively on the continent of Europe, especially in France, where a great portion of the supply of sugar is obtained from the juice of these sap-roots. In Great Britain beet-root is eaten as a pickle, and mangold-wurzel is largely grown as winter food for cattle.

2. Sugar-maple (*Acer saccharinum*, Wang.; natural order, *Aceraceæ*).—From the juice which flows from incisions made in the stem of this, and probably other species of maple, large quantities of a coarse uncrystallisable sugar are manufactured in North America.

3. Date (*Phœnix dactylifera*, L.; natural order, *Palmaceæ*).—From this useful palm, and also from *P. sylvestris*, L., and *Saguerus saccharifer*, sugar is produced by boiling the juice, which flows from incisions made in the flower-heads; from *P. sylvestris*, L., alone, thousands of tons are made annually. These sugars are mostly consumed in India; much, however, is supposed to be imported to England as cane-sugar. The fruit of the date is well known and highly appreciated in Britain. It is remarkable for its nutritious and life-sustaining qualities; the Arabs, while crossing vast desert tracts, requiring no other food than a handful or two of this fruit per day. The best grows in the regions on the southern slopes of the Atlas mountains. This part of Africa is said to be the natural habitat of the date-palm, and is called *Bil-ed-uljerid*, or the Date Country.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—II.

It has been explained in previous lessons that "to bisect" means to cut into two equal portions; this requires to be properly understood in dividing angles, for it will be evident that if a line were drawn *across* the angle, the one part would be much wider than the other, even though the line might cross exactly in the middle of one of the lines forming the angle. The following problem shows the correct method of overcoming the difficulty, and subsequent figures show the application of the lesson.

***To bisect an angle*, A B C (Fig. 8).**—From B, with any radius,

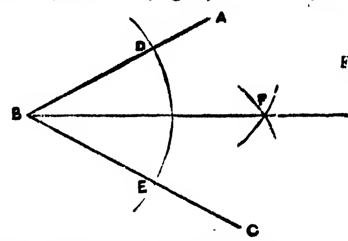

Fig. 8.

describe an arc, cutting the lines B A and B C in D and E.

From D and E, with any radius, describe arcs cutting each other in F.

Draw B F, which will bisect the angle.

To inscribe a circle in the triangle A B C (Fig. 9).—Bisect any two of the angles (by Fig. 8).

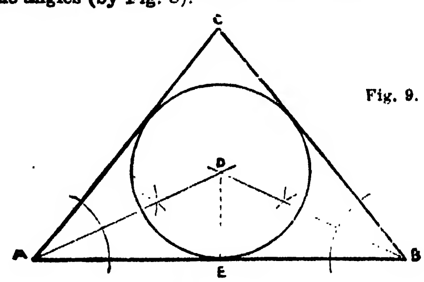

Fig. 9.

Produce the bisecting lines until they meet in D.

From D, with the radius D E, which is a perpendicular from D on A B, a circle may be described which will touch all three sides of the triangle. This is called the *inscribed* circle.

To draw a circle through three points, however they may be placed, provided they are not in an absolutely straight line (Fig. 10).

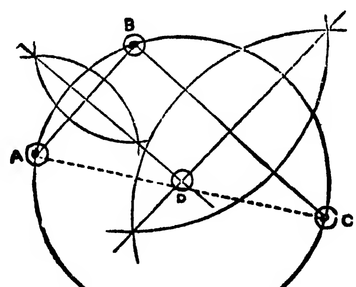

Fig. 10.

Let A B and C be the three given points. Join A B and B C. Bisect A B and B C, and produce the bisecting lines until they cut each other in the point D.

Then D will be equally distant from each of the three points. Therefore, from D, with radius D A, D B, or D C, a circle may be drawn which will pass through the three given points.

It will be evident that if A and C were joined, the figure would be a triangle; and thus this problem serves also for describing a circle which shall touch the three *angles* of a triangle. This is called the *circumscribing* circle.

The Gothic trefoil (Fig. 11).—The trefoil is a figure much used in Gothic architecture. It is formed of three leaves, or lobes (hence its name), meeting at a centre, as in the three-leaved clover. It is sometimes enclosed in a circle, as in window tracery, but not always, as in many wall-piercings. This figure will serve as an application of the construction of the equilateral triangle and the bisecting of angles. It is here introduced with the view of showing students the importance of *absolute* accuracy in the early problems, as well as in the subsequent operations.

Construct an equilateral triangle, *a b c*.

Bisect the angles, and produce the bisecting lines, *d*, *e*, *f*.

Observe, that in an equilateral triangle, the lines which

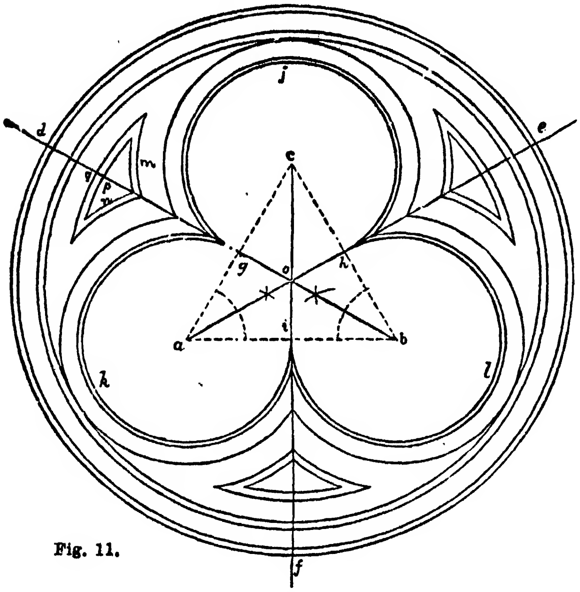

Fig. 11.

bisect the *angles* will, if produced, bisect the *sides* opposite to the angles as well, and thus the points *g*, *h*, *i* are obtained.

From *a*, *b*, and *c*, with radius *a g*, equal to half the side of the triangle, describe the arcs *j*, *k*, *l*, and the others, which it will be plain are concentric (that is, drawn from the same centre) with them. The arcs *m* and *n*, and those corresponding to them, are also drawn from the same centres.

The outer circles and the arcs *p*, *q*, etc., are drawn from the centre of the triangle *o*.

To construct on the given line, D E, *an angle similar to the angle* A B C (Fig. 12).

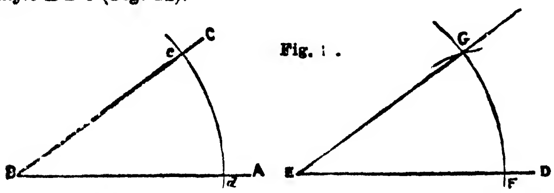

Fig. 12.

From B, with any radius, describe an arc cutting the sides of the angle in *c d*.

From E, with the same radius, describe an arc, cutting E D in F. Measure the length from point *c* to *d*. Mark off the same on the arc from F—viz., to point G. Draw a line from E through G. The angle F E G will be equal to A B C.

On the given line, A B, *to construct a triangle similar** to C D E (Figs. 13 and 14).—At A construct an angle similar to the angle H C G—viz., J A I.

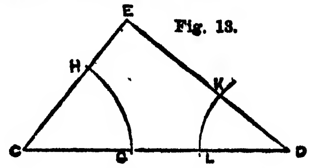

Fig. 13.

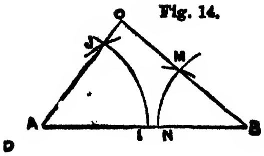

Fig. 14.

At B construct an angle similar to the angle K D L—viz., M B N. Produce the lines A J and B M until they meet in O; which will complete the triangle required.

Definitions concerning four-sided figures which are not parallelograms.—A figure having four sides, which are neither equal

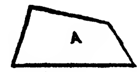

Fig. 15.

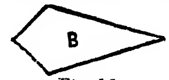

Fig. 16.

Fig. 17.

nor parallel to each other, is called a *trapezium*, as A (Fig. 15).

But any two of its adjacent (or adjoining) sides may be equal to each other, so long as they are not parallel to the opposite sides, as B (Fig. 16).

If any two of the sides are parallel to each other, the figure is called a *trapezoid*, as C (Fig. 17).

To construct a trapezium similar and equal to another, C D E F (Figs. 18 and 19).

Draw A B equal to C D.

At A construct an angle similar to that at C.

Make A G equal to C E.

At B construct an angle similar to that at D.

Make B H equal to D F.

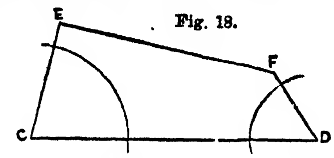

Fig. 18.

Join H G, and the trapezium on A B will be similar and equal to C D E F.

It is advisable that the students should be repeatedly exercised in constructing figures similar and equal to each other; and as the correct result of the higher figures depends on the refinement of their construction, the most *intense accuracy* should, from the very outset, be aimed at.

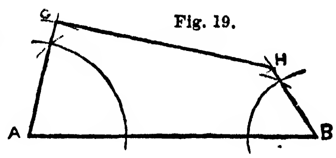

Fig. 19.

Having thus illustrated the difference between the trapezium and the trapezoid, and between similar and equal, we now proceed to construct these figures similar to others, and of given dimensions. The artisan cannot too soon begin to work to "scale," and he is therefore recommended to take the measurements from his rule, not from these pages; the result must be the same, even though the mere sizes may be different.

To construct on the given diagonal, A B (Fig. 20), *a trapezium similar to another,* C E D F (Fig. 21).

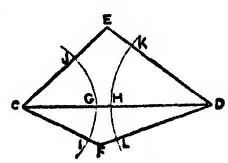

Fig. 20.

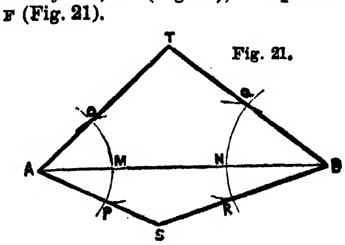

Fig. 21.

Draw the diagonal C D in the given trapezium. From C and D, with any radius, draw arcs cutting the diagonal C D in G and H, C F and C E in I and J, and D E and D F in K and L. From A and B, with the same radius, describe arcs cutting the diagonal A B in M and N. From the point M, cut off on the arc the length G J—viz., to O, and also the length G I—viz., to P. From the point N, cut off on the arc the length H K—viz., to Q, and also the length H L—viz., to R.

Draw B Q and B R; also A O and A P. Produce these lines until they meet in S and T. A T B S will be the trapezium required.

* When a figure is said to be *similar* to another, it means that it is of the same *shape*. When it is said to be *equal*, it means that it is of the same area—that is, it contains precisely the same *space*. A figure may be equal to another without being similar in shape: thus a square may be equal in area to a rectangle; and a figure may be *similar* without being *equal*, as in Figs. 13, 14. "*Similar and equal*" means being of both the same *shape* and *size* as another figure, as in Figs. 18 and 19.

This result would be the same, whatever might be the length of the diagonal or the relative sizes of the figures, as an angle is not altered by the length of the lines of which it may be formed.

To construct a trapezium from the following given dimensions (Fig. 22).—Sides C A and C B are to be adjacent to each other, forming an angle similar to A B C. C A is to be 1¾ inches long; C B, 1¼ in.; A D, 1 in.; B D, 1¼ in.

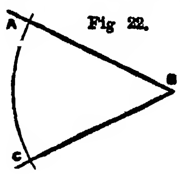

Fig 22.

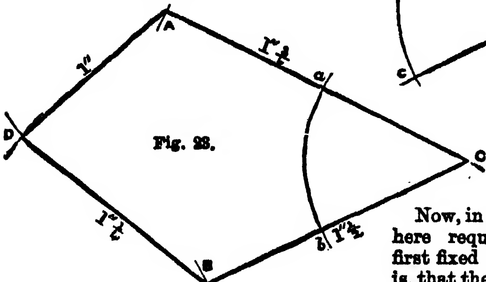

Fig. 23.

Now, in the figure here required, the first fixed condition is, that the sides C A and C B are to make an angle similar to the given angle A B C. Therefore at any point, construct this angle (a C b), and produce the lines until C A is 1¾ inches, and C B 1¼ inches long—viz., to A and B.

From A, with 1 inch radius, describe an arc. From B, with 1¼ inch radius, describe another arc cutting the former in D. Draw A D and B D, which will complete Fig. 23 from the given dimensions.

COLOUR.—II.

By A. H. CHURCH, M.A., Professor of Chemistry, Royal Academy, London.

COMPOSITION OF LIGHT—COMPLEMENTARY COLOURS—THE SPECTRUM.

NEWTON was the first to discover that white light was compound. To split up a ray of the solar light into its constituents, the following contrivance (Fig. 1) may be adopted:—Through a hole in the shutter of a darkened room a beam of light, S, enters. This beam falls upon a prism of flint-glass, A, so arranged that the side, P, opposite to its refracting angle is uppermost and horizontal. The beam will be refracted and dispersed, as described in our last paper; and if the refracting angle of the prism be 60°, a vertical

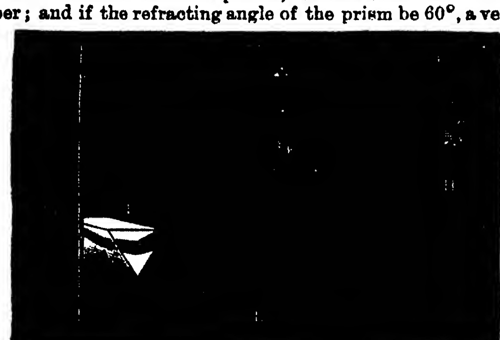

Fig. 1.

band of rainbow colours will be produced on a screen placed at a distance of five yards or so from the prism, A. This band, H I, is the solar spectrum. It consists of a very large number of different tints, amongst which it is easy to distinguish seven principal colours. Beginning at the end of the spectrum which is nearest to the spot, K, which the beam would have reached in the absence of the prism, we find the order of the colours is as follows:—Red, orange, yellow, green, blue, indigo, violet. Now the mode in which these colours have been separated from white light is sufficient proof that they cannot be further separated into other kinds of colour. This anticipation is realised by actual trial; for if, as in Fig. 2, one of the colours of the spectrum, v, be allowed to pass through a hole in the screen, E, on which the band of decomposed light has been received, it cannot be altered by being transmitted through a second prism, B. The ray will be refracted, of course, but it will show but one colour, as before, and its image will not be elongated.

We have already learnt that every ray of coloured light has its own wave-length, and therefore that all the colours of the spectrum, however similar they may seem, are really distinct tints. But this consideration does not take in all the facts of the case. The green of the solar spectrum is not compound, but simple; and yet we know that many substances of a green colour may be split into two components, one blue and the other yellow. Supposing for a moment we can exactly imitate the

Fig. 2.

green of the solar spectrum by mixing yellow and blue pigments together, this fact would not of itself suffice to prove that the solar green was really a mixed hue; but it would show that the sensation of vision is similarly excited by the waves that reach the eye from these two colours—one simple, the other apparently compound. Precisely the converse of this holds good. We can, as might be expected, re-form white light by re-uniting all the seven dispersed coloured lights of the solar spectrum (we will describe how to do this presently); but we can reach the same result by re-uniting merely certain pairs of these coloured lights. Thus, the following unions of two colours generate white, or nearly white light:—

1. Red—greenish-blue.
2. Orange—Prussian-blue.
3. Yellow—indigo-blue.
4. Greenish-yellow—violet.

These pairs of colours, and many others less easy to distinguish by intelligible names, when united lose their respective colours and become white. They are called *complementary* colours. It will be seen that we have followed in our grouping of them the sequence of the colours of the spectrum, beginning with the red or least refrangible rays; but in order to produce white light by the combination of any couple of the above colours, two conditions must be fulfilled—the intensity and the quantity of the component rays must be adjusted with care. By receiving two such coloured pencils of light upon a lens which condenses and brings them to the same focus on a white screen placed at a suitable distance, the result is a perfectly white light; but, to secure this result, the constituents of a coloured ray are as important as its apparent quality of colour. Thus Helmholtz has found that the red and bluish-green of the spectrum produce yellow, not white; while red, with the bluish-green formed by the union of green and indigo, does yield white. Green and red have indeed a relation to each other which is different in some particulars from that of many other pairs of colours. They, however, are often included among the pairs of so-called *complementary* colours for reasons to be hereafter noticed. That there is something very peculiar in the relation of green to red may be also concluded from the frequency with which these two colours are confounded by persons who suffer from colour-blindness or Daltonism.

One of the most curious of all the results of studying the re-composition of white light is the relation of yellow to blue. It is a matter of observation that a yellow and blue liquid and a yellow and blue powder, when mixed together, produce respectively a green liquid and a green powder. But a very different result ensues on mixing blue and yellow light together. When the blue and yellow rays of the spectrum are mixed together, white light is produced. The same effect results from receiving upon the eye the reflected image of a disc painted with gamboge along with the direct image of a second disc painted with cobalt-blue. Though a disc painted with these two pigments mixed together would have appeared green, yet when the lights these pigments respectively reflect are conveyed to the retina as above described, then, where the two images coincide, whiteness is the result.

We must now describe some of the peculiarities of different spectra, and afterwards a few of the more recondite methods by which colour is produced.

Our purest source of coloured lights is a spectrum. We may use the spectrum of the solar beams, or that from the electric lamp: the latter is more convenient, and yields, as we have previously stated, a light more complex than the sun; for in the solar spectrum there are some three thousand or more gaps where rays are missing. These are the black lines first noticed by Wollaston, in 1802, afterwards mapped out by Fraunhofer, and at last explained by Bunsen and Kirchhoff. These black lines indicate lost rays—rays which have been blotted out by absorption. The absorption takes place in the following manner:—In the sun's gaseous envelope certain vapours exist. These vapours are opaque to certain rays of light: they do not allow them to pass, but quench them. There is, for instance, the metal sodium in the sun's gaseous covering. Now sodium vapour is opaque to a certain yellow ray which it itself originates when it is burnt. Consequently, the place which should be occupied by a bright yellow band in the solar spectrum is a dark line, or rather group of lines, called D. In like manner the other black lines, or many of them, have been traced to the special absorptive powers possessed by the sun's gaseous envelope, and exercised upon certain rays of light emanating from within. These black lines, however, in the solar spectrum, though rendering it imperfect in continuity, are of great service in referring to the localities of particular colours. Yet we must not forget that the material of the prism exercises some influence upon the position of the lines and the relative extent of the coloured bands. In the coloured plate (TECHNICAL EDUCATOR, Vol. II.) are shown the positions occupied by the most important of the black lines and coloured spaces in the solar spectrum when obtained by means of a flint-glass prism in the spectroscope. The conditions of success in obtaining these lines distinctly are a narrow, clean-edged slit, a collimating lens to make the luminous rays parallel, and a prism of highly-refractive and dispersive glass, quite free from striæ and flaws. The instruments known as spectroscopes are, however, always of more complicated construction than these conditions seem to involve; for it is desirable to use a battery of prisms instead of one prism, and to obtain a magnified image of the spectrum by means of a combination of lenses in a telescope. Let us turn now to the consideration of the spectra as obtained by means of the spectroscope.

Most of our sources of artificial light yield spectra without lines. An oil-lamp, gas-flame, the electric light, are instances of this kind. But it is easy to secure a flame which shall yield a very simple spectrum, reduced by the absence of so large a number of rays that it shall merely consist of a few bright bands, or merely of one. Dissolve a little common salt, for instance, in some methylated spirit of wine, and introduce the solution into a spirit-lamp. The flame will, to the eye, appear tolerably luminous and distinctly yellow. The spectrum of this flame shows little more than a single brilliant yellow band, occupying the dark space of the solar spectrum called D. The metal sodium is distinguished from other metals by its flame emitting rays of that particular refrangibility only. If a salt of lithium be taken, and dissolved in spirit, the flame of the lamp will be crimson, and two coloured bands will characterise the spectrum. One of them is red, and very distinct; the other is of a faint orange tint. Other metals produce different spectra, though in many cases the colour which they impart to the flame of a Bunsen gas-burner or a spirit-lamp may seem to the unassisted eye identical.

In trying experiments with coloured flames, in order to study their effects on the appearance of different objects, the following contrivance may be used:—A (Fig. 3) is a Bunsen gas-burner (which is best made of steatite); B is a bundle of fine platinum wires, dipping into a small vessel containing a mixture of a solution of the metallic salt to be experimented with, and ammonium chloride. A ball of pumice attached to a bundle of asbestos fibres may be substituted for the platinum wires. The following is a list of substances which give colours of different hues to the flame of a burner under the circumstances described, the metallic salts most applicable being those known as chlorides, chlorates, and nitrates:—

Substances.	*Colours of Flame.*
Calcium nitrate	Red.
Lithium chloride	Carmine.
Strontium nitrate or chlorate	Crimson.
Sodium chloride	Yellow.
Barium chloride or chlorate	Yellowish-green.
Boracic acid	Green.
Thallium perchloride	Green.
Copper chloride	Bluish-green.
Indium chloride	Indigo-blue.
Potassium chlorate	Violet.

The above substances give, for the most part, spectra with many bright lines of different colours; but the red lines will dominate in one spectrum, and the green in another.

Thus far we have been studying light and colour by means of the prism: we will now see how the colours of the spectrum may be separated without that instrument, and yet without loss of any of their component parts. Some of the most beautiful phenomena of colour are produced by a modification which light undergoes when it passes the edge of an opaque body, or when it traverses a small opening. Light then turns a corner. This bending of the waves of light has been termed *diffraction*. The source of light in studying the phenomena of diffraction should be a luminous or highly illuminated point. A silvered bead, or steel globule, or the focus of rays obtained by the action of a lens on a beam of light entering a dark chamber by means of a small hole—all these contrivances furnish a suitable light. If a narrow rectangular slit between two metallic edges be placed in a beam of light, between the focus of a lens and a screen, the space between the edges will be occupied by bands of coloured light. If one colour only be used, as by the interposition of a screen of red glass, then alternate bands of that colour and black will be seen. By using, instead of a simple rectangular slit, apertures differing in size, number, and shape, very beautiful chromatic appearances may be developed. These may be obtained by looking at a bright point or line of light through a bird's feather mounted in a card-frame, through a piece of glass dusted with lycopodium spores, through a fine wire-grating, through piece of very fine cambric, or through a plate of smoked glass ruled with fine lines.

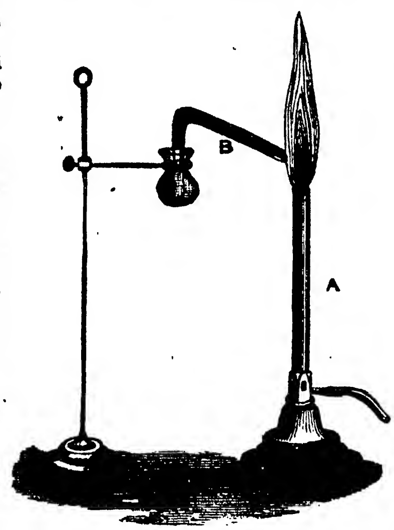

Fig. 3.

The halo of colours sometimes seen round the moon and the sun is a phenomenon of the same kind, produced by the diffraction of light by the globules of water constituting the fog. Imperfectly polished metals, the feathers of many birds, and the surfaces of mother-of-pearl, owe part, at least, of the peculiar coloured effects which they exhibit, and which are known as iridescence, to the diffraction of the light reflected from the small striæ, filaments, or folds of their surfaces.

Now, without entering into the minute particulars necessary to elucidate these appearances thoroughly, we may state that the phenomena of diffraction are due to two causes. One of these is the bending of light round a corner, as waves of water bend round a rock in a lake; the other, the interference of the waves of the light-rays so bent with one another. Interference of one set of oscillations with those of another set may even extinguish the light altogether. This takes place when the crests of the undulations of a ray coincide with the hollows of the undulations of another ray: thus there will be rays on each side of a slit which, bent by diffraction, will by this kind of interference exactly neutralise each other and abolish the light.

The dark bands and lines produced by diffraction are explicable in this way. As to the cause of the colours seen under the conditions just mentioned we may refer to the

obliquity of the paths of the diffracted rays. If red light be employed, black and red rings or bars alternate; but with violet light, black and violet rings or bars are seen. The violet rings are nearer together than the red, because their waves are smaller than the red. We can obtain bands of colours intermediate in width between red and violet by employing, for example, green light. Hence, when *white* light passes through a slit, we obtain a series of coloured spectra side by side, because the constituent colours are not superposed, owing to the obliquity of the paths of the rays and their different wave-lengths. More or less obliquity in the path of a diffracted ray will cause it to differ, by various parts of a wave-length, from other diffracted rays of the same beam.

The colours of thin plates correspond in sequence, as do those of diffraction, to the colours of the prismatic spectrum. They are produced by the interference of the ray which enters the thin transparent film, and is reflected from its second surface, with the ray which is directly reflected from its first surface. A soap-bubble may be of such a thickness as to retard the beam reflected from its second surface by half a wave-length, or by any number of half wave-lengths. Then it will be found that the bubble is black, because the two reflected beams are in complete discordance; and a destruction of light follows. Then, again, soap-bubbles may vary very much in the thickness of different parts. As the waves of light differ in length, so they will require different thicknesses to produce accordance and discordance. The result of this is that a thickness of film which is competent to extinguish one colour will not extinguish other colours. Thin films of variable and changing thicknesses, illuminated by white light, will therefore display in their different parts variable and changing colours. The colours of the precious opal are due to the interference of the internal reflections from its minute vacuous fissures. The colours of tar-films upon water, of many insects' wings, and of lead-skimmings, are due also to interference. So also are the splendid chromatic appearances of certain crystals when viewed in polarised light, and, to some extent also, the colours previously alluded to as iridescent.

We will next turn our attention to the production of colour by "selective absorption," to the re-composition of white light by the re-union of its scattered elements, and then to the mutual relations of those coloured elements.

THE ELECTRIC TELEGRAPH.—II.

By J. M. Wigner, B.A., B.Sc.

INSULATORS (*continued*)—TESTING THEM—MODE OF MAKING JOINTS—LIGHTNING CONDUCTORS—COVERED WIRE—MODE OF MAKING JOINTS IN IT.

However perfect the insulators employed on any line may be, there is sure to be some slight escape of the current, and our care is to reduce this to a minimum. Dust and dirt settle on the insulators, especially when they are damp, and thus allow some portion of the electricity to escape to the post. Formerly a screen was placed over the insulator, to shield it from the rain; but it is now found that when there is a good glaze to the earthenware, the rain washes off the dirt, so that after long-continued dry weather a smart shower will frequently materially improve the insulation of a long line: the screen is consequently dispensed with.

Glass and different glazes also condense the moisture of the air on their surfaces, and thus produce a damp layer, by which the current escapes. In this respect ebonite is found to be superior to any substance of a vitreous nature, but at present its durability and economy have not been sufficiently tested, and it is but little adopted for general purposes. When, through defective insulators, or in any other way, the current leaks to the ground, the line is said to be "earthy," and usually the defect may be remedied by an increase of the battery power. If a full contact is made with the ground, so that the whole or the greater portion of the current is lost, there is said to be "dead earth."

Very frequently a portion of the current leaks from one wire to another, and in this way the messages along both lines are rendered more or less indistinct. There is then said to be "contact." Spiders' webs round the wires will, when they become damp, act thus, and where the lines cross public streets, they are frequently fouled by the strings of kites. These strings becoming broken in the attempts made to save the kite, get twisted round the wires, and in damp weather greatly interfere with the communication.

In earthenware insulators cracks are not unfrequently produced by the unequal shrinking of the wire in drying or baking, and if these are covered with a glaze they may escape detection at first. After a while, however, the glaze cracks, and then the flaw becomes apparent by the escape of the current. A good glaze is useful, since it hinders the adherence of dirt and dust, but it must not be depended upon as an insulator.

All insulators should, before being employed, be carefully tested, so that defective ones may be rejected. This is usually done by immersing the porcelain or earthenware portion for a few hours in dilute sulphuric acid, or in salt and water. One pole of a battery is then applied to the stalk of the insulator, and the other is immersed in the liquid, a delicate galvanometer being introduced into the circuit, and in this way a flaw is easily detected. In a few cases a portion of the glaze is removed, so as to test the quality of the ware itself.

On a very wet day it is often found difficult to communicate with distant stations on account of "weather contact," or the leakage of the current along the insulators and posts. In such a case it is frequently found very advantageous to join a fresh set of batteries side by side with the others, so as to increase the quantity rather than the intensity. Two batteries thus joined side by side are, of course, equivalent to one having cells double the size.

The following experiments tried by Mr. Walker, of the South-Eastern Railway, illustrate this well. The figures in the last column indicate the strength of the current received at the further end, as shown by a quantity galvanometer. The line was a defective portion, five or six miles long:—

Cells.	*Size.*	*Strength.*	*Cells.*	*Size.*	*Strength.*
24	Ordinary . .	10	48 . .	Double . . .	37
24	Double . . .	24	72 . .	Ordinary . .	21
24	Treble . . .	27	72 . .	Double . . .	43
24	Sixfold . . .	32	96 . .	Ordinary . .	23
48	Ordinary . .	19			

From this it will be seen that a greater power was obtained from forty-eight cells connected in pairs (twenty-four double cells) than from ninety-six connected in the ordinary way.

In many of the telegraph wires that cross the roofs of houses in large towns, a form of insulator different from any hitherto described is employed. It consists of a short cylinder of porcelain (Fig. 5), with a hole pierced along its centre, and a broad groove round it, so that it somewhat resembles a short and stout reel. The wire is then passed round the groove, and fastened off as at an ordinary terminal insulator. Another wire is passed through the central hole, and by this it is affixed to the post. The wire at the other side of the post is fastened in a similar way, so that two insulators are required at every post. As, however, they are of a very simple form, consisting merely of a lump of porcelain, their cost is but small. A short link of wire is connected beyond the insulators on each side, and forms the passage along which the electric current passes. This plan is found much more simple and economical for carrying the wires over houses. If any wire breaks, only the length between the two posts is affected, and can easily be repaired; it is also easier to stretch the wires when fastened in this way.

Wire cannot easily be obtained in lengths of more than about a thousand yards, and usually it is made in shorter pieces; frequent joints have, therefore, to be made, and the manner of making these is a thing of very great importance. It is not sufficient merely to make a strong joint, which shall bear the strain: we must also ensure a complete electrical contact; and as, after a while, the wire becomes more or less oxidised, great care is necessary, or else in a short time the current would be seriously impeded, or even altogether interrupted. The joint most frequently employed in England is that known as the Britannia joint, and is represented in Fig. 6. The ends of each of the pieces of wire to be joined are first carefully scraped and cleaned, so as to remove all oxide. About half an inch at the end of each is then turned up at right angles, and the two pieces being laid side by side for two or three inches, are carefully and tightly bound round with galvanised binding wire. The bent ends should then be cut short, as otherwise, when

blown about by the wind, they are apt to hook the next wire, and thus make a false contact.

In order to make the joint more secure, the whole is very frequently made tight by soldering, and many engineers consider this of the utmost importance; but in towns it is almost given up, and little or no practical inconvenience is found to accrue. It adds, however, to the strength to employ solder, since the wires sometimes become injured by the twisting, and then, after a time, yield and break.

The other joint commonly employed is the twist joint, and in France it is almost universally adopted (Fig. 7). To make this it is necessary to have the ends of the wires quite soft and pliable, as otherwise they will break off short, and cause much inconvenience and delay. When carefully cleaned, they are laid side by side for about five or six inches; the end of each is then carefully and tightly twisted round the other, a space of about an inch being left in the middle, to avoid turning the wire too sharply, and thus injuring it. In order to make this joint, it is necessary to have a clip of some kind to hold the wires firm while they are being twisted. The French usually employ two small screw-clamps fitted with handles, and with the aid of these the joint is easily made. In England an ingenious arrangement, consisting of two steel bars, jointed in the middle, is used. One or other of these two joints is almost universally adopted.

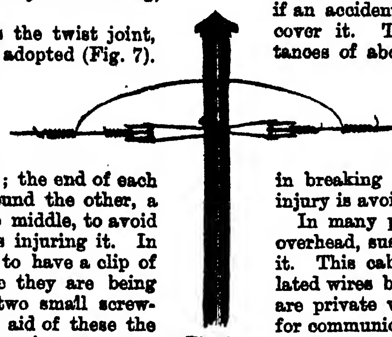

Fig. 5.

The wire employed is carefully tested for strength, and also for ductility. Short pieces of it are gripped between two vices six inches apart, which are then twisted in opposite directions, and the wire should stand from fifteen to thirty twists, according to its size, before it breaks; it is also tested by the application of weights so as to find its breaking strain. As few welds as possible should be allowed, and these should be carefully tested, as it is usually at these places that the wire breaks. It is a very good plan, when stretching the wires, to draw them as tight as practicable by means of a block, and then let them be pulled sideways with considerable force. In this way they will be straightened, and the weak places very probably detected. They may then be pulled tighter and fastened to the insulators.

Fig. 6.

Fig. 7.

When a number of wires are placed on the same posts, care is required to ensure a sufficient distance between them, as otherwise, when they become a little slack, and are swayed by the wind, they will touch. The lateral interval, when the posts are at the usual distance of about sixty yards, should be at least twelve or thirteen inches, and the vertical distance ten inches. If the posts are further apart, greater distances should be given.

When the wire is affixed to a terminal insulator it should not be twisted, as in that case it is very likely to break. The end should be slightly turned up and then passed round the insulator, and securely bound after the plan shown in section at Fig. 8.

Telegraph posts should always be provided with a pointed wire projecting above the top, and connected with the ground, so as to serve as a lightning conductor. From their elevation they attract the lightning, and were it not for these conductors, it would pass along the lines and often do serious damage to the instruments or fittings.

In most cases the wires are suspended in the air in the way we have been explaining. Occasionally, however, they are placed beneath the surface of the ground or the sea; and then, of course, they must be insulated along their entire length. Sometimes, to avoid the inconvenience of fixing wires on the roofs of houses, or the danger of their crossing public thoroughfares, they are laid under the paving stones at the side of a street. The usual plan is to lay a metal pipe in a narrow trench, and to place the wires inside this pipe so as to protect them from accidental injury. Copper wire is usually employed, and as it is a much better conductor than iron, and has no strain to support, it may be used of a much less diameter.

The simplest plan of insulating it, and that almost universally adopted, is to apply a coating of gutta-percha to it. This is carefully laid on when quite soft and warm, and on cooling forms a firm protection, and being a good insulator prevents the escape of the fluid. Sometimes a second or third coating of gutta-percha is applied outside the first, so that if an accidental flaw exists in the one, the other may cover it. The wires are usually brought up at distances of about a mile, into iron pillars arranged for the purpose, so that in the event of any interruption of the communication, the wires can be tested, and the exact position of the fault ascertained. In this way much unnecessary trouble in breaking up the streets to discover the place of the injury is avoided.

In many parts of London, a small cable may be seen overhead, suspended from two wires placed a little above it. This cable contains a large number of separate insulated wires bound together in one bundle. Most of these are private wires employed by different business houses, for communicating with branch offices, or manufactories. The instruments commonly used in these cases will be described in a future paper. The wires being coated with gutta-percha are completely insulated from one another, and single ones are brought out of the bundle at any required place.

In a few instances subterranean lines are laid for considerable distances, but in these cases some additional protection is usually given, as it is found that the gutta-percha alone, if exposed to the air, or to moist ground, perishes in a few years and becomes almost useless. On this account all external connections from offices which are made with this wire (and most are made with it) ought to be covered with tape, and to receive a good coating of Stockholm tar once or twice every year. When this is done they will last almost indefinitely. In very exposed positions, it is better to protect them still further by enclosing them in a pipe, or putting a wood-casing round them. It is, of course, unnecessary to insist on the great importance of taking all such precautions.

As this wire is so much used, especially in important positions, it will be well here to explain the way in which joints may be made in it.

A few narrow strips of the very thin sheet gutta-percha should be in readiness, and also a little warm gutta-percha about one-eighth of an inch thick. One or two tools for heating, and a spirit-lamp are also required. Having softened the wire by warmth, the covering may very easily be stripped off with a knife for just as far as is requisite to make the joint. The ends should be well cleaned, joined, and soldered in the usual way with the twist joint. Sometimes, as an additional precaution, the joint is bound with thin wire before soldering. The gutta-percha on the wire beyond the joint should be softened and tapered down to the wire.

Fig. 8.

Now take a narrow strip of the thin sheet, and fixing it to the warm tapered part, twist it spirally along all the joint, and fasten at the other side. Having done this, gently warm the surface; then lay on in the same way as before a second strip, wrapping it round in the reverse direction, and warm again. Sometimes a third strip is added as an additional safeguard, and in important places it is well to do so. Outside this lay on a layer of the thicker gutta-percha, taking care to make a good contact with that covering the wire beyond the joint, and smooth and finish off the whole with a warm tool. With care and cleanliness, a joint thus made is as secure as the rest of the wire. Moisture or dirt, however, if allowed to enter during the process, will impair the joint very much.

APPLIED MECHANICS.—III.

BY SIR ROBERT STAWELL BALL, LL.D.,
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EXPERIMENTS ON THE THREE-SHEAVE PULLEY-BLOCK — DIFFERENTIAL PULLEY — EPICYCLOIDAL PULLEY — CONCLUDING REMARKS.

THE three-sheave pulley-block has been described in "Mechanics."—XIV. (POPULAR EDUCATOR, Vol. III., page 396). Our duty is to describe the mode of experimenting with it, to record the results, and to explain their significance.

One experiment will be fully explained, as by this means the process will be better understood. The sheaves were about 2''·5 in diameter, and the rope used was what is called technically "imperial patent sash line." A weight of 228 lb., not including the weight of the block itself, was attached to the hook of the lower block. According to the theory of virtual velocities, a power one-seventh of this should be sufficient to raise this load, but a power of 38 lb. was found not sufficient, though if the load were raised a little, 38 lb., or indeed less, would prevent it from overhauling. It was found that a power of 56 lb. was necessary in order to raise the weight, so that the power is seen to be about one-fourth of the load, instead of one-sixth. A series of experiments with different loads was tried, and the result is given in the table below.

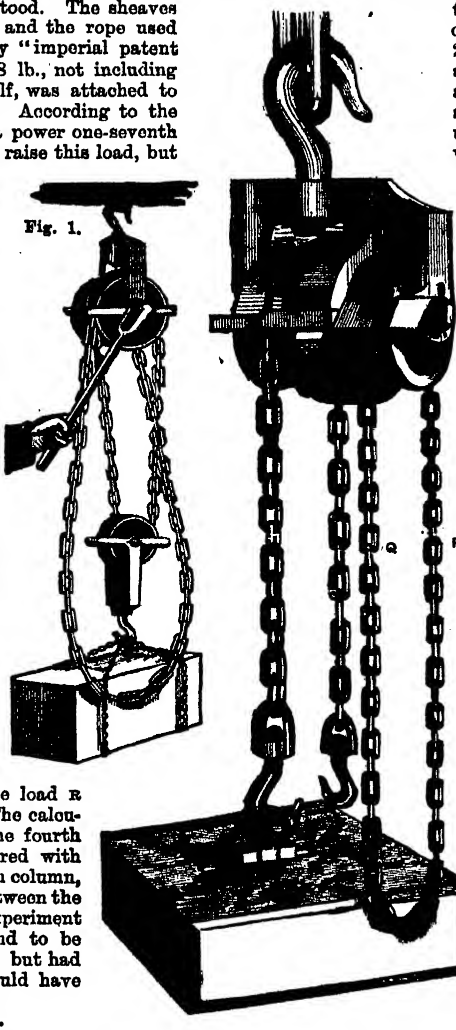


Fig. 1.

Fig. 3.

The first column shows the number of each experiment, (there were eight in all); the second column gives the load, which was in each case suspended from the lower pulley-block; and the third column gives the corresponding value of the power. From columns 2 and 3 the formula—

$$P = 2{\cdot}36 + 0{\cdot}238\ R$$

has been calculated to be that which represents the relation between the power P and the load R with the greatest fidelity. The calculated values are shown in the fourth column, and they are compared with the observed values in the fifth column, which shows the difference between the two. Thus, for example, in Experiment 7 a load of 395 lb. was found to be raised by a power of 97·0 lb.; but had we used the formula we should have found—

$$2{\cdot}36 + 0{\cdot}238 \times 97 = 96{\cdot}4.$$

THREE-SHEAVE PULLEY-BLOCK, SHEAVES 2''·5 ON WROUGHT-IRON AXLES. FORMULA $P = 2{\cdot}36 + 0{\cdot}238\ R$.

Number of	Load in lb.	Observed Power in lb.	Calculated Power in lb.	Difference of Observed and Calculated Values.
		15·5	15·9	+ 0·4
	114	29·5	29·5	+ 0·0
3	171	43·5	43·1	− 0·4
4		56·0	56·6	+ 0·6
5	281	70·0	69·2	− 0·8
6		83·0	82·8	− 0·2
7	395	97·0	96·4	− 0·6
8	453	109·0	109·9	

On examining the table it will be seen that the difference, 0·6, between the calculated power and the observed power is shown in the fifth column. It will be noticed that the differences between the calculated and the observed values are always very small. This shows that the formula represents the experiments with accuracy.

THE DIFFERENTIAL PULLEY-BLOCK.

A pulley-block which has been introduced within the last few years, and which has been found of the utmost practical utility, has been called the Differential Pulley-block. It is a convenient adaptation of a mechanical principle which, though of considerable antiquity, was never applied in practice until the invention of this machine. The principle of the machine will be understood from Fig. 2, which shows in a diagrammatic form the action of the pulley, while its general appearance is given in Fig. 1. It consists of a fixed and a movable block, and an endless chain. The upper block, A (Fig. 2), is composed of two sheaves, which are, however, in one piece, and turn together. The diameter of one of these sheaves is a little greater than the diameter of the other. The lower block, B, differs from the ordinary movable pulley only in having small ridges in its groove, in order to receive the links of the chain properly. An endless chain connects the two blocks; the course of this chain is indicated in the diagram by the arrows. Starting from P, where the power is applied by the hand, the chain passes over the larger sheave, then down under the movable pulley, then up again around the smaller sheave, and back again to P.

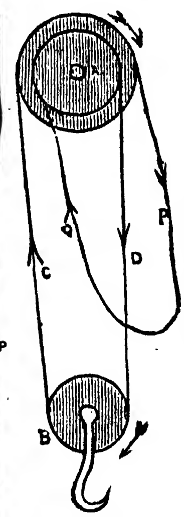


Fig. 2.

The action of the machine will now be easily seen. The upper block winds up the chain on the side marked C, and at the same time lowers it on the side marked D, as indicated by the arrow; but since the circumference of the groove by which the chain is raised is greater than the circumference of the groove by which it is lowered, it follows that the chain must be wound in a little faster than it is lowered out; hence the pulley, B, must be raised gradually. The origin of the name is then evident: the raising of the load is due to the difference of these actions. By having the chain endless, a much smaller length of chain will suffice than would otherwise be necessary.

velocity ratio of the differential pulley is most easily ascertained by measurement. Thus, in a pulley of this class which is adapted for raising weights up to a quarter of a ton, the velocity ratio is 16. This was found by observing that sixteen feet of chain must be pulled out of the upper block in order to raise the hook one foot. But the mechanical efficiency of this machine is by no means sixteenfold. Attaching 5 cwt. to the hook, it is found that 86 pounds must be attached to the chain in order to raise it. The power is most conveniently attached to the chain by means of little hooks, which pass through the links, and can receive the rings attached to the weights. Hence, from this experiment we see that the mechanical efficiency is 6·6, or roughly, six or seven-fold. Thus, in the use of this machine, though the power of a man is enabled to lift a weight six times greater than would be pos-

sible without this assistance, yet more than half of the energy or work which he puts into it is consumed by friction. This apparent loss of energy is not only useless, but, unfortunately, as energy is never really lost, what is not usefully employed expends itself gradually in abrading the parts of the pulley, producing what is known as wear and tear. To resist this as far as possible, the working parts of the differential pulley are specially hardened.

It often excites surprise in one who sees for the first time a differential pulley in action, that when the weight has been raised it will remain suspended without the chain being held or fastened. This property of not overhauling is one of the most useful features of the pulley. It is not only very convenient, but is a source of safety, as accidents often occur when heavy weights are raised by machines which do not possess this property. In fact, in the use of the differential pulley, when the weight is to be lowered the chain Q must be pulled, just as P must be pulled when it is being raised; by holding one of these chains in each hand the position of the weight can be adjusted with the greatest nicety. This adds very much to the general utility of the differential pulley, and renders it a mechanical aid of great value.

That the differential pulley does not overhaul, arises solely from the fact that more than half the power which is applied is lost by friction, and therefore when friction acts to prevent motion it is more than sufficient for the purpose. This property applies to all the mechanical powers where the mechanical efficiency is less than half the velocity ratio; as, for example, in the screw, but not in the three-sheave pulley-block.

The handle which is attached to the upper block of Fig. 1 shows a modification of the differential pulley, which is sometimes useful; by turning this lever the block is turned round, and therefore the load is raised; by having a long lever the power can be greatly increased. By this means a man is enabled to lift a ton or even more without using any very great exertion, but the rate at which the weight is raised is, of course, very slow.

EXPERIMENTS UPON THE EPICYCLOIDAL PULLEY.

In Fig. 3 we have represented another kind of pulley, which is often called the epicycloidal pulley-block. In this there are two chains—one stout chain with a hook at each end, on which the load is carried; the other a smaller chain, which passes over a sheave in the upper block, and by means of which the power is applied. Holding one part, P, in one hand, and the other part, Q, in the other hand, the weight can be raised and lowered with the greatest facility. The mechanical power of this pulley is about fivefold, and as its velocity ratio is 12, it follows from the principle already laid down that the weight cannot overhaul.

There being two distinct hooks on the load-chain, one of these hooks is always low down and convenient for raising, when the other has carried up its load. This is a practical convenience which, as the student may have noticed, is not met with in the differential pulley.

CONCLUDING REMARKS.

The values of the velocity ratios and mechanical efficiencies which have been given in this lesson for differential pulleys apply only, of course, to the actual specimens which have been examined. Various sizes of differential pulley-blocks are made, but the one here referred to is that size adapted for lifting a quarter of a ton; the more general principles apply to all sizes, but it was thought better to describe fully one form. The same remark may be made about the epicycloidal pulley-blocks.

Various other blocks differing more or less from those mentioned are met with. The way to study them is to perform the two processes here described. First, measure the distance through which the power must be moved when the load is raised one foot; then attaching a given load to the load-hook, see what power will raise it. The first operation gives the velocity ratio; the second, the mechanical efficiency. A comparison of these numbers, which would be equal in a perfectly frictionless machine, shows how much of the power is lost by friction. And we cannot repeat too often, that when the mechanical efficiency is reduced by friction to less than half the velocity ratio, the machine does not overhaul.

CHEMISTRY APPLIED TO THE ARTS.—III.

BY GEORGE GLADSTONE, F.C.S.

DYEING (*continued*).

In the practical operation of dyeing the first thing that has to be considered is the material to be dyed. The same processes cannot be applied to cotton, flax, wool, silk, etc., indiscriminately; in fact, it may be taken almost as a general rule that one which will suit a vegetable fibre will not suit those derived from the animal kingdom. It is not, however, sufficient merely to divide the articles to be dyed into these two classes, for cotton and flax will not dye equally well by the same process, nor will a given amount of dye-stuff produce the same effect upon wool after it is spun or woven as before—one quality, too, of either wool or cotton will take up colours much more readily than another. Nowadays there is a great disposition to use mixed goods as articles both of dress and furniture, in which cotton and silk, or cotton and wool, or a mixture of the latter with goats'-hair, are woven together. All such, if they are to be subsequently dyed, demand much consideration as to the means to be adopted.

The animal substances are, in nearly all cases, the most susceptible to the dyer's art, more brilliant colours being produced upon silk than on any other material. Woollen goods also dye very well; the scarlet of our soldiers' coats, which is produced by cochineal mordanted with oxide of tin, being a colour the equal of which cannot be attained on any vegetable tissue. It is, therefore, a matter of no little difficulty to dye a mixed fabric of an even colour.

By the aid of chemical solvents, if other means fail, the dyer can at once detect any mixture in the materials of which the cloth to be dyed is made. For instance, bichloride of tin, when heated moderately, will turn vegetable fibres black, while animal substances will remain unaltered. If a mixed fabric of cotton and wool be boiled in caustic soda, the wool will be dissolved and the cotton will remain untouched. Again, cotton is whitened by chlorine, but silk and wool are turned yellow. Having determined this point, the next step is to prepare the article for dyeing. Of whatever material the goods may be made, it is necessary to free them from grease, iron-mould, or any other accidental impurity; and if they are to receive any light or delicate tints, they must be properly bleached. If the goods are fresh from the manufactory, they are sure to contain either grease or some dressing; and if they are old, there will probably be some accidental stains, which will reappear more or less after dyeing, if they are not first eradicated.

The material being thus prepared, the subsequent processes will depend much upon the article of which it may be made. Confining our attention at present to simple fabrics, we must take them separately.

Silk.—To produce a good colour, silks should first be immersed for some hours in a strong solution of alum, which must be dissolved in cold water, for if applied hot it is injurious to the lustre of the silk. After the aluming, they should be thoroughly washed in pure water. A good permanent red may then be produced by a mixture of cochineal with bitartrate of potash and spirits of tin. For a yellow, weld is very commonly employed, the silk being put into a hot solution in which some soda is dissolved, the quantity of the latter depending upon the shade desired, an increase of the soda rendering the colour more intense. For blues, recourse is generally had to indigo, with the addition of a little potash and madder, the vat being kept moderately warm during the process. There is, however, considerable difficulty in producing an even colour with this dye, and the silk should be dried rapidly when taken out of the vat. To obtain an intense black, it is necessary to deprive the silk, as much as possible, of the gummy substance naturally belonging to it, which is done by boiling it in a strong solution of soap—a desirable thing, by the way, in every case, as all the colours take better the more thoroughly the gum is removed. This being done, it is steeped for a day or a day and a half in a very strong decoction of galls, or one of the other substances mentioned in the previous article as having the same chemical property, after which it is immersed in a solution of sulphate of iron. Greens are usually produced by dyeing the silk yellow in the first instance, and then blue. Violets and purples may be obtained by dyeing first with cochineal (no tin being added to it in this case) and subsequently with indigo, the relative

strengths of the two dyes being adjusted according to the tint desired. For all these combinations, however, the aniline dyes are now superseding the others, on account of the great beauty of the tints. They have a great affinity for silk, and the operation is consequently very simple: a solution of the dye is made in cold water, and the silk worked in it until it has acquired the requisite depth of colour.

In all cases the silk, after being taken out of the dye, must be washed in cold water before being hung up to dry.

Wool.—Care must be taken to rid the stuff of the grease it always contains by scouring it well in soap and water or a strong solution of soda for several hours. It is then ready to receive the dye, which is always to be applied hot, the wool being afterwards washed in cold water. It can be dyed blue by indigo in the manner described in the previous article for dyeing cotton, except that the vat must be kept at an elevated temperature. For woollens, however, the vat is more generally prepared in another way, and goes by the name of the "pastel vat." The difference consists in substituting for the sulphate of iron and the large quantity of lime, other ingredients for deoxidising the indigo, one of them acting the part of a dye at the same time. Pastel or woad was, indeed, used almost exclusively 200 years ago for dyeing blue, but has since been quite superseded by indigo, on account of the latter giving a richer colour. To prepare a vat, about 400 lb. of woad, 20 lb. of madder, 10 lb. of bran, and 8 lb. of lime have to be boiled up together. In the course of twenty-four hours it will be in a state of fermentation, and the bath will have acquired a yellowish tint. It is then ready to receive the indigo—say about 20 lb., with a further addition of about half that weight of lime—and in about six hours more the indigo will be converted into the white soluble state previously described. The wool is then dipped in the vat for about an hour, after which it is hung up in the air to dry, during which process it turns blue; the dipping being repeated several times if very deep shades are required. This vat, when once prepared, will last for months, but the supply of indigo must be renewed from time to time as its strength becomes exhausted.

The substances employed for dyeing red in all cases require a mordant to fix them. If madder be used, the cloth should be first steeped in a solution of alum and bitartrate of potash. To produce a brilliant scarlet, a little cochineal should be boiled up with bitartrate of potash and spirits of tin; and after the wool has been dipped in this mixture, washed, and dried, it should be immersed in a second bath containing a strong solution of cochineal. Lac is used for the same purpose, and with the same mordants. To obtain a good black, the wool is first dyed blue, then boiled in a solution of galls or any of the other articles previously named which possess the same properties, and finally in a bath of sulphate of iron. For a green it is generally found best to dye the stuff blue first, and afterwards yellow. For violets and purples the blue should form the foundation, though some shades of these compound colours may be made in the bath by a mixture of the various ingredients, by which a saving is effected in the number of operations. Mauve and the other aniline dyes also act very readily upon wool by merely working it in a lukewarm aqueous solution.

Vegetable fibres are not so readily dyed as those already considered, nor can colours of equal brilliancy be produced upon them. After the fabrics made of them have been properly cleansed they are subjected to the operations of aluming and galling. The materials used for these purposes are sufficiently indicated by the respective terms.

Flax.—After being thus prepared, it may be dyed red with madder by a process similar to that used in dyeing cotton Turkey red, which will be considered presently. This is almost the only shade of red which can be produced as a fast colour on vegetable tissues. Quercitron furnishes a beautiful and permanent yellow. For blues, indigo is almost invariably employed. A thorough black is not readily obtained, but the most approved plan is first to dye the linen with a deep blue, then steep it in a strong decoction of galls, and finally in a bath containing one of the salts of iron along with acetic acid.

Cotton is generally dyed in the same way as flax. The mode of using indigo has already been described in detail in the previous article. The Turkey red process is certainly the most complicated of all, but it demands special notice, as it is very extensively carried on, particularly in Glasgow and Manchester, and produces one of the most durable colours known. The little minutiæ must inevitably be omitted for the sake of brevity, and only the most characteristic operations described, though very great exactitude in all the details is necessary in order to produce a thoroughly satisfactory result. The cloth, having been carefully freed from the weavers' dressing, is steeped three successive times (being dried on the grass between each) in a bath containing the following ingredients to 15 gallons of cold water:—1 gallon of olive oil, 1½ of sheep's or cow's dung, 4 gallons of a solution of carbonate of soda, and 1 gallon of a solution of pearl-ash. The steeping in this liquor should last for a fortnight at least. The cloth is then passed through a warm and weak solution of pearl-ash, steeped again three times as before in a bath containing 1 gallon of olive oil and 3 of soda lye to 18 of water; and then passed again through a wash of soda and pearl-ash. These may be considered the preparatory processes, the chief peculiarity of which consists in the use of oil and dung, which together act as a mordant upon the outer surface of the cotton fibre, and prepare it to take up the dye that is subsequently to be applied. The alkali through which the fabric is passed saponifies and carries off any excess of oil remaining over from the preceding operations, the rest being apparently decomposed by the action of the other ingredients with which it is mixed. The cloth is next galled with a decoction either of gall-nuts or sumach, and then alumed, without which the dye would not be permanent. The colouring matter used is madder, to which some bullock's blood is added, the quantities varying according to the intensity of the colours required. The fabric is put into the dye when cold, which is then raised to the boiling-point, and kept at that temperature for a couple of hours. It is finally boiled in an alkaline solution in which a little protochloride of tin is dissolved, and then spread out to dry. The great peculiarity of this process is, that while the usual object to be attained in dyeing is to fill the internal cavity of the transparent fibre with a colouring matter which shall be insoluble, the Turkey red dye is principally deposited on the outer surface, and has entered into actual combination with the fibre itself—a circumstance to which both the permanence and the brilliance of this dye are attributed. Mauve, or any of the aniline colours, will dye cotton; unlike silk or wool, however, the fabric must be mordanted in order to produce a fast dye. It is best to soak it first in a decoction of sumach, galls, or other article rich in tannin, then pass it through a solution of stannate of soda, and lastly dilute sulphuric acid. Then the cotton will absorb the dye most readily.

Hitherto attention has been directed to the dyeing of fabrics made exclusively of one material. The mixed goods have also to be dyed, and that either of one or more colours; for instance, a damask may be dyed of one uniform colour, or the cotton may be of one and the wool of another. In either operation the affinity of the materials for different colouring matters has to be taken into consideration, as well as the manner of applying them; picric and rosolic acids, for instance, cannot be used for dyeing cottons, nor are the compound cyanides of potassium and iron applicable to woollens. With mixtures of cotton and wool it is nearly always necessary to dye the latter first, as it is more tenacious of the colours imparted to it; but if the cotton is to be blue the order of proceeding is reversed, the indigo dye being so fast as to be unaffected by the subsequent operations upon the wool. It is not so easy to produce different colours upon a mixture of silk and wool, because they are both animal substances, and are each more or less acted upon by the same ingredients; the silk, being more retentive, is, however, generally dyed first. With a mixed fabric composed of silk and cotton the same order is followed.

There are two ways of dyeing mixed fabrics of one uniform colour—either separately or at one process. Let us suppose that a mixture of cotton and wool has to be dyed black. The latter can be dyed first with camwood and sulphate of iron in the manner already described, and then the cotton in a solution of sumach followed by sulphate of iron. They may, however, be dyed simultaneously (and even if the fabric should also contain silk the process will apply) by steeping the article in a decoction of sumach, and then in a solution containing equal parts of bitartrate of potash, sulphate of iron, and sulphate of copper; after this with logwood, and again with the sulphate of iron. Other colours besides black may be produced upon mixed goods by a single process; the adjustment of the in-

gredients needs, however, considerable nicety, in order to adapt them to the varied powers of the materials in taking up the different dyes.

Throughout this chapter it has been taken for granted that the materials are the best of their respective sorts. Many of them unavoidably vary considerably in quality, while others, again, are in such a condition as to be easily adulterated. It is very important, therefore, that the operator should be thoroughly assured both as to the purity and quality of the ingredients, or he may be grievously disappointed in the result.

PROJECTION.—VII.

CYLINDERS AND CONES.

PLAN AND PROJECTION OF A SPEED-PULLEY (Fig. 89).

THIS is a further application of the lessons on the projection of cylinders, wheels being, as it were, sections cut from cylinders. The subject is composed of three pairs of parallel circles. Having drawn the plan, describe on A B a semicircle, and divide it into any number of equal parts in *c*, *d*, *e*, *f*, *g*. From each of these points draw lines meeting A B at right angles in *c' d' e' f' g'*. These lines will cut C D in *c''*, *d''*, *e''*, *f''*, *g''*. Draw a line, X X, at a height above I L equal to the radius of the circle—viz., *e' e*. From A B, and all the points between them, draw perpendiculars passing through X X, and on these perpendiculars set off on each side of X X distances corresponding to the distance between the point similarly lettered in the semicircle and the line A B, as *e e'*, *d d'*, etc., and this will give the points A', B', C', D', E', F', G', through which the ellipse is to be drawn. From each of the points last mentioned, draw horizontal lines, and intersect them by perpendiculars from the points C, *d''*, *e''*, etc., in the plan, and the intersections of the lines correspondingly lettered will give the points E'', D'', A'', etc. The other two wheels are to be projected in precisely the same manner from semicircles equal to half their surface. The lettering of these is omitted in order to avoid confusion in the diagram; but the student, who is expected to work on a much larger scale, is advised carefully to letter every point.

CONES AND THEIR PROJECTION.

A cone is a solid, the base of which is a circle, and the body of which tapers to a point called the *apex*.

The straight line drawn from the centre of the base to the apex of the cone is called the *axis*.

When the axis of the cone is perpendicular to the base, the cone is called a "*right*" cone; but when otherwise, it is called an "oblique" cone.

The curved surface of a cone is equal to the sector* of a circle, the radius of which is equal to a straight line drawn from any point in the circumference of the base to the apex, and the arc-line of the sector is equal to the circumference of the base of the cone.

Fig. 90 is the plan and elevation of a cone when standing on its base, its axis being perpendicular to the horizontal and parallel to the vertical plane. The apex is thus over the centre of the plan, and the solid is therefore called a *right* cone.

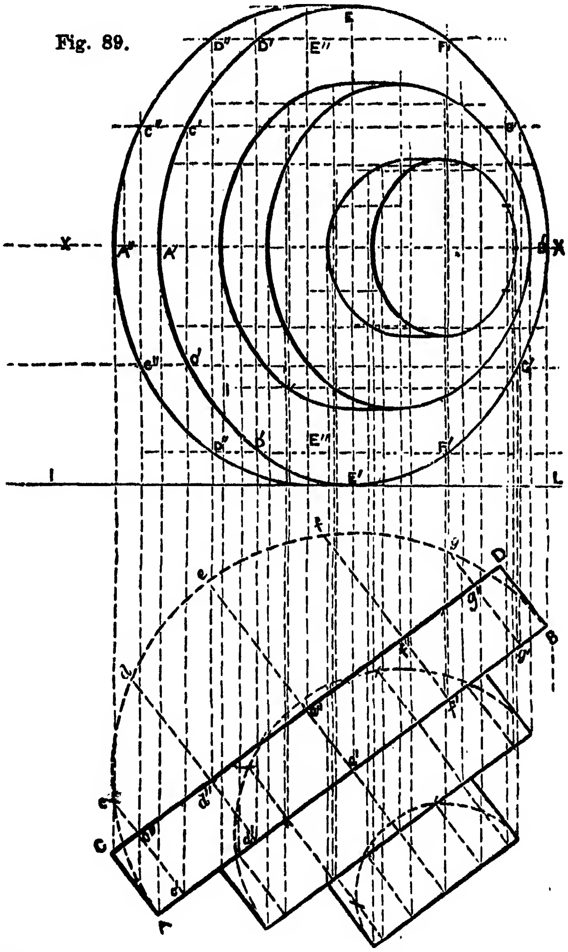
Fig. 91.—To draw the plan of this cone when lying on the horizontal plane with its axis parallel to the vertical plane, draw the elevation lying on I L. To do this, at any point in I L construct an angle similar to A B C in the elevation; make the sides of the angle equal to those of the elevation, and join A' C'. Bisect the angle, and produce the bisecting line to D. This will be the axis. Now begin the plan by drawing C B parallel to I L. From D in the elevation, with radius D A', describe a semicircle, and divide it into any number of equal parts in *e*, *f*, *g*, *h*. From each of these points draw lines meeting A' C at right angles, and from these points of meeting drop perpendiculars passing through C B on the points *e*, *f*, D, *g*, *h*. Set off from these points on their respective perpendiculars, and on each side of C B, the lengths of the lines between A C and the semicircle, and by this means the points through which the ellipse is to be drawn will be obtained. Join the point B to each end of the ellipse, which will thus complete the plan. The students should now, as an exercise, turn the plan so that its axis is at a given angle to I L, and then make a projection from it and the present elevation.

* A sector is a part of a circle contained between two radii and a portion of the circumference.

Fig. 92 shows the elevation and plan of the cone when resting on the extremity of one diameter of the base, the plane of which is at 30° to the horizontal plane.

It will be evident that whether the cone lies on the paper, or stands on one extremity of a diameter of its base, so long as the axis remains parallel to the vertical plane, the elevation will be the same in *form*—changed only in position—and therefore the line which is the elevation of the base has been placed at the required angle. Construct on it an isosceles triangle of the given altitude, which will form the elevation of the cone. It must here be remarked that this figure and the next have been left unlettered, so that the student may become gradually accustomed to follow the points through their various change of position; and, with Fig. 91 to guide him, it is thought that he

Fig. 89.



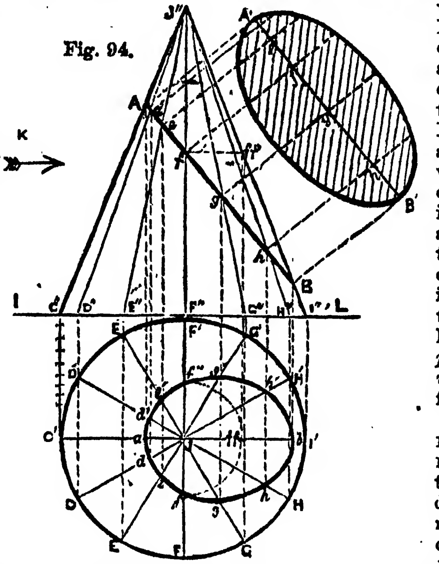
will be able to complete this projection of the plan from the instructions here given.

It will be remembered that although the base of the cone is rendered by a straight line in the elevation, that line is the *edge elevation* of a *circle*; therefore, from the middle point in the line describe a semicircle, which will represent one-half of the base, turned up so as to be parallel instead of at right angles to the vertical plane. Now divide this semicircle into any number of equal parts, and from each of these draw lines at right angles to the diameter. Next draw a line in the horizontal (or lower plane) parallel to I L, and a portion of this line will become the axis of the cone. From each of the points in the base of the cone draw perpendiculars passing through this horizontal, and make them the same length on each side as the lines drawn from the points in the semicircle to the diameter. Through these points trace by hand the ellipse, which represents the plan of the base, being the view from a point imme-

diately over it. Drop a perpendicular from the apex of the elevation to cut the horizontal, and this intersection will be the plan of the apex. Join this by straight lines to the widest parts of the ellipse, and this will complete the projection.

Fig. 93 is the projection of the cone when the base is at 30° to the horizontal, and its axis at 45° to the vertical plane. It has been shown in several previous figures that an object may be rotated without the height of any part of it being altered; and thus, as in the projection now required, the base of the cone is to be at an angle to the horizontal plane similar to that of the last figure, the plan will be the same in shape, but altered in position; therefore, repeat plan of Fig. 92, placing it so that the axis is at 45° to I L; then draw perpendiculars from all the points in the ellipse, and cut them by horizontals from the points in the elevation. Draw the projection of the base through the intersections. Draw a perpendicular from the point which is the plan of the apex, and a horizontal from the apex in the elevation. The intersection of these will give the apex of the projection. Join this point to the ellipse representing the base, which will complete the figure.

Fig. 94.



SECTIONS OF CONES.

If a cone be cut across, so that the plane of section may pass through the axis at an angle, and cut the slanting surface of the cone on the opposite sides, the section is called an *ellipse*.*

TO DRAW AN ELLIPSE WHICH SHALL BE THE TRUE SECTION OF A CONE ON A GIVEN LINE.

Let Fig. 94 be the plan and elevation of the cone, and A B the line of section. Divide the circumference of the plan into any number of equal parts in C′, D, E, F, G, H, I′, and D′, E′, F′, G′, H′, and draw radii. Project these points on to the base of the cone, and from C″, D″, etc., draw lines to the apex J″. The diagram up to this point represents a cone, up the slanting surface of which straight lines have been drawn, which on looking down on the apex would appear as radii of the circle forming the plan.

The line E″ J″ in the elevation is therefore the radius E J in the plan, and thus the plan of any point marked on E″ J″ must fall somewhere on the radius E J. Now the section-line A B cuts through all the lines drawn to the apex of the cone in the points *d, e, f, g, h*, and it will be remembered that, although in the elevation the section is represented by a single line, A B, it will assume a different form in the plan. From points A and B draw perpendiculars cutting the diameter C′ I′ in *a* and *b*, and from *d, e, g, h* in the elevation draw perpendiculars cutting the radii of the plan which bear the same letters. Draw the curve, which will unite *e′d′ade*, and also the curve uniting *g′h′b hg*. It will at once be seen that these two curves form the ends of an ellipse which is to be the *plan* of the section, but that a point is wanted on F and F′ in order to complete the figure. But we cannot draw a *perpendicular* from the point *f* in the elevation, to cut the radius F in the plan, as we have done in the other lines, *because the radii* F F′ *are but portions of the same perpendicular on which the point f is situated*, and therefore no intersection can be obtained.

Now let us remember that the line F″ J″, though appearing perpendicular to I L when looked at in its present position, would, if looked at from K, in the direction of the arrow, be seen to be as much a portion of the slanting surface of the cone as I″ J″, and therefore the line F″ J″ would be seen to make the same angle with the horizontal plane as I″ J″. If therefore we rotate the cone on its axis, the point *f* will move to *f f*, and a perpendicular drawn from *f f* will give us *f f* in the plan. If now we turn the cone to its original position (which will be represented by drawing a quadrant from the centre of the plan with radius J *f f*), the quadrant will cut the radius F in *f′* and F′ in *f″*. Join *e* and *g* and *e′* and *g′* by curves passing through *f* and *f′*, which will complete the plan of the section. This is not the *true section*, but the view when looking straight down upon it, and as it is slanting, its length from *a* to *b* will seem shorter than it really is. It will be evident that the true length of the section is the line A B. From these points, and also from *d, e, f, g, h*, draw lines at right angles to the section-line, and A′ B′ parallel to it. On each side of the points *d, e, f, g, h*, in the line A′ B′, set off the distances which the points similarly lettered are from C′ I′ in the plan, and these will give the points through which the true section may be drawn.

Fig. 90. Fig. 91.

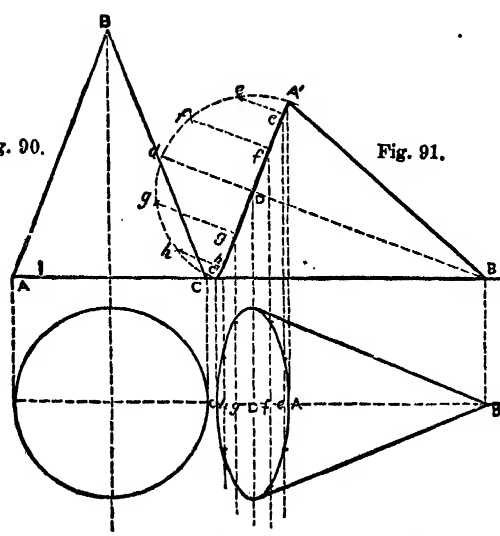
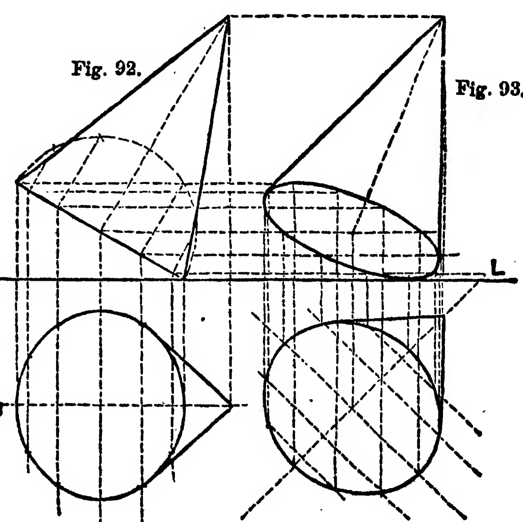


Fig. 92. Fig. 93.



* An ellipse differs from an oval by being the same shape at both ends; but in an oval, the one end is more pointed than the other.

TECHNICAL EDUCATION AT HOME AND ABROAD.

III.—THE BUILDING TRADES AND APPLIED ART INDUSTRIES.

BY SIR PHILIP MAGNUS.

THUS far I have tried to indicate some of the advantages of affording technical education to the ordinary workman and to apprentices engaged in our large manufacturing concerns. I have dwelt on this somewhat fully, because it is often said that technical education is of very little, if of any, use to the ordinary hands engaged in a large mill, or in a mechanics' shop, or in chemical works—that there must be "hewers of wood and drawers of water" until the end of time, and that no amount of special instruction can be of service in improving the workman whose duties are wholly mechanical, and who himself forms a part, so to speak, of the machine he uses. To the ordinary workmen who are employed in passing red-hot bars of steel through metal rollers, or in dipping hanks of yarn into coloured dye-stuff, or in joining here and there a thread that breaks as the automatic mule moves to and fro, or in watching the shuttle carry its weft through the mass of warp dexterously divided by the guiding cards, it may seem that technical instruction can avail little in improving their position, or in developing the industry in which they are engaged. But further consideration shows that, whilst all such men are rendered more efficient by becoming more thoughtful, more painstaking, and more trustworthy, when properly instructed through the medium of their trade, the seeds of education, scattered widely among such men, here and there yield fruit which benefits not only themselves, but all those who depend upon their labour, and upon the knowledge that directs it, for the necessaries and for many of the luxuries of life.

BUILDING TRADES.

I come now to speak of a class of operatives who are assisted far less by machinery, and whose success very greatly depends upon their manual dexterity, their technical knowledge, and artistic skill. To workmen such as these, the advantages of technical education are considerable. The smith, the plumber, the carpenter and joiner, the metal-plate worker, the bricklayer, the mason, and many others are engaged on work requiring manual skill that can be obtained by practice alone, and at the same time knowledge of the properties of the materials they use. It is of importance to the plumber to understand the difference between blow-pipe solder and copper-bit solder, and to know which is the better to use in a particular kind of metal-work. It is important to the metal-plate worker to know how to cut a sheet of metal so as to make an elbow-joint without wasting material. It is important to the painter to know what influences affect different kinds of paint, and how these influences may be obviated. Such knowledge of the properties of the materials used, and of the action on them of natural agents, is of the utmost value to the workman. To supply this knowledge, technical schools have been established in which a youth may have the experience which he acquires in the workshop supplemented, or may be taught his trade, and trained as a workman. In many parts of the Continent there exist schools in which boys learn all the details of a trade, the practice of which does not require any extensive machinery, just in the same way as they would do in a shop. In these schools, manipulative skill is acquired, and the principles of the different branches of science bearing upon the trade are also taught. Such schools are called "Apprenticeship Schools," and several of them will be described later on. The industries to which I now refer are not those on which the commercial prosperity of a country mainly depends. They are not manufacturing industries. The workmen engaged in them are not employed to the same extent, as in many other trades, in producing articles for export, and manual skill and knowledge of the properties and capabilities of the materials used are more important. These industries, however, employ a very large number of hands, and there are many persons who, when speaking of technical education and of its benefits to the working classes, have only these and similar trades in view. Indeed, much of the divergence of view on this vexed question of technical instruction arises from the fact that different persons, when speaking or writing about it, have very often in their mind a different set of trades and different classes of workmen. The manufacturer thinks of technical education in reference to the "hands" he employs. The builder has in mind the bricklayer, the plumber, the carpenter, and the gas-fitter. The cabinet-maker, the carriage-builder, the printer, etc., each thinks of the kind of training that would be most serviceable to the persons he employs.

Now, although in all manufacturing centres the greater number of the working men and women are employed as "hands" in the several factories of the town in producing goods of one sort or another, there must necessarily be even in these towns a large proportion of persons occupied in other trades. In our principal cities these smaller trades probably engage the greater part of the artisan population, and it is from them that the demand for technical instruction on the part of artisans has mainly arisen. All kinds of machinery are so rapidly improving, that many of the things which, a few years since, the carriage-builder, or pianoforte-maker, or watchmaker, or shoemaker, made for himself, are now produced by some mechanical process. There are trades, however—and it is to these that I am now referring—still in that stage of progress when skilled labour is of the utmost value, and when consequently technical education is greatly beneficial. The healthy condition and the comfort of our dwelling-houses depend not only upon the care with which they are designed, but also upon the skill with which the work in all parts of the building is executed. In the laying of the bricks, in the fixing of the doors and windows, in the plastering of the ceilings, in the arrangements connected with drainage, with the supply of water and of gas, the security and sanitary condition of our houses depend mainly upon the skill of the workman and upon the technical knowledge of those who overlook him. And no mere empirical knowledge, derived from practical experience only, or obtained by imitating the work of others, is sufficient to guide the builder and those he may employ in successfully overcoming the difficulties he may meet in new and unexpected combinations of circumstances. The improvements that have of late years been effected in dwelling-houses are mainly applications of the principles of physical and chemical science. The removal of foul air from rooms, the prevention of smoky chimneys, the construction of grates, the making of gas-jets, the determination of the best material for water cisterns, the ventilation of soil pipes, the complicated considerations connected with traps, are all questions the solution of which involves a knowledge of the principles of various branches of science; and it is this knowledge, and its application to these questions, which constitute the technical education of the builder. It is only of late years that the health of the people has been shown to depend to so great an extent upon the condition of the dwellings they inhabit. The fact that disease may be prevented—indeed, that it is more easily prevented than cured, is one of the great achievements of scientific discovery; and the connection that has been established between disease and the quality of the air we breathe and of the water we drink, has rendered it absolutely necessary that, if our homes are to be healthy, builders should understand the principles of science that bear upon their trade, in order that they may be able so to construct our houses as to prevent our air from being contaminated or our water from being defiled.

ART INDUSTRIES.

Now, without attempting to exhaust the various classes of industry to which technical training is applicable, and in connection with which some education in science has become indispensable, it is necessary to refer to those trades or occupations in which artistic skill is the main element of success. If there is any one fact of which we have recently been made fully aware, it is that in spite of the multiplication of art classes during the last ten years, throughout the length and breadth of the land, we are still far behind our Continental neighbours in artistic skill; indeed, we are only gradually coming to understand that although it is reserved to few persons only to develop into skilled artists, every one can, and should, be taught to draw. To excel in literature is an accomplishment which few can hope for, but nevertheless every one may be taught to express his thoughts clearly and grammatically in English prose. In the same way every child, if properly instructed, may and should be taught to draw, and when we come to describe

foreign schools, we shall see how this subject is looked upon abroad.

In England, it frequently happens that an artist produces a design for a piece of work which is ill-adapted to the material in which it is to be expressed, although it might possibly be very well executed in some other substance. Such errors in design are far less common in France; and if we seek out the cause, we shall find that in France, much more than in England, the artisan has had opportunities of familiarising himself with beautiful objects from his earliest childhood. In French cities, the shop windows are more gaily decorated than they are in this country; there are more museums and ancient palaces; and, owing possibly to the more genial climate and partly to temperament, the Frenchman visits such places far more frequently than his insular and home-loving neighbour. Hence it comes about that, owing to early training and constant familiarity with beautiful objects, the artisans of France and of other foreign countries are more cultivated in their tastes than English workmen; and the man who designs patterns to be wrought in any particular material, has himself worked in that material, and is perfectly familiar with its capabilities and with the general character of the design which can be adapted to it. In England this is seldom the case. The designer to any particular trade is a man who has been brought up as an artist, and has subsequently turned his attention to making patterns. He can probably sketch correctly from nature, and has a certain facility in making happy combinations, but he does not possess the knowledge of the man who has spent several years of his life in working in the material to which the designs he makes are to be adapted. Now, where artistic skill is widely diffused among the workmen themselves, designers abound, and they can be selected for each particular trade from those who have worked at that trade and are thoroughly familiar with its requirements.

To large classes of artisans, skill in modelling is almost as essential as the ability to draw. The teaching of modelling is now beginning to make progress in Great Britain, but until within the last few years the schools in which modelling was taught were very few indeed. Abroad, this is not the case. In many foreign schools modelling is taught almost as generally as drawing, and it is quite certain that in many arts the one is quite as useful as the other. In sculpture, whether in wood or stone, and in many branches of metal-work, modelling is very necessary, and in designing for those arts the skilled modeller has a great advantage over the artist, whose fingers are not equally sensitive to the perception of form in relief.

The use of machinery in the production of goods has not been without effect on designing, and has rendered technical instruction even more necessary than before. In many industries, as we have already seen, designs that may be excellent works of art *per se* are often found to be unsuited to the material in which they are to be executed, owing to the artist's ignorance of the capabilities and characteristics of that material. This additional requirement is commonly spoken of as a perception of the *technique* of the material, and the designer possessing this special qualification for his work may be said to be familiar with "technical art."

TECHNICAL DRAWING.—IX.

DRAWING FOR CARPENTERS (*continued*).

WOODEN BRIDGES.

FIG. 56 is the elevation of the bridge over the Weser alluded to in the last lesson. The bow, built up as described, abuts against oak blocks, toothed and bolted on to the ends of the tie-beam. From the bow, transverse bearers are suspended by means of seven iron rods, placed as in the drawing, and on these the beams supporting the roadway rest.

It is deemed necessary, in relation to the drawing of this example, to remark that the lines forming the joints (that is, the ends of each piece of timber) must be radii of the circle of which the arc is a part. In the present instance the arc is that subtending an angle of 60°; therefore, having drawn the tie-beam, and marked the points at which the under side of the bow meet it, with distance between these two points as radius, describe arcs cutting each other in a point below, which would be the apex of an equilateral triangle, and from this centre the arcs are to be described.

The disadvantages connected with the De Lorme system are, first, that the stiffness of the span must depend mainly upon the natural strength with which the fibres of the wood adhere to each other; and as this is of course limited, it is necessary to construct the curved rafters of greater width than would otherwise be required, in order to ensure them against the strain to which they may be subjected. Secondly, there is, from the circumstance above alluded to, and from the necessity of sawing the segments out of straight timber, a great waste of material, time, and labour.

These considerations naturally prevented the system becoming very general, and in 1809 an improvement thereon was proposed by a celebrated Prussian architect named Wiebeking, which was in 1817 perfected by Colonel Emys, a French military engineer, and which has since been extensively used.

By Emys' system, the arched ribs are laminated—that is, formed of "laminæ," or thin layers of timbers—not placed edgeways, as in the De Lorme plan, but laid flat on each other, the break-joint system being still preserved, and the planks being held together by iron straps with which they are surrounded.

The whole rib is then confined by its ends fitting into cast-iron shoes bolted on to the tie-beam. Thus all the fibres of the wood coincide with the curvature of the rib, and thus not only are they not liable to be torn asunder, but a great amount of elasticity is obtained. As this system has been extensively used in the construction of roofs, it will be further described in the section devoted to that subject, and the attention of the student is now directed to the elevation of one of three arched ribs of a wooden railway bridge (Fig. 57).

Here the tie-beam is formed of double timbers, resting on an additional piece at each end.

The bow is made up of seven layers of timber, united in the manner shown in Fig. 58, which is an enlarged drawing of the middle portion of the truss.

Seven perpendiculars are placed between the bow and the tie-beam, by which the latter is suspended, as by king and queen posts. The mode in which the iron bands, nuts, and screws act in such cases is described in connection with Roofs in "Lessons on Building Construction."

The trusses are further stiffened by diagonal struts between the perpendiculars. Across the tie-beams of the three ribs the sleepers are placed on which the flooring of the bridge and the rails are laid.

The piers, saddle-pieces, and tie-beams having been drawn, the arc forming the upper edge of the bow is next to be described. The cast-iron shoes necessarily follow. In the smaller view (Fig. 57) their outer edge is shown as continuous with the arc of the bow; but in working this figure to a larger scale, this should be drawn with a rather wider radius, so that the iron shoes may project to allow for the thickness of the material. As in the case of the cross-joints of the timbers in the De Lorme bow truss, the third side of the cast-iron shoes and the bands by which the laminæ are clamped together are radii of the circle of which the bow is a part, and therefore converge to the same centre. This is not, however, the case with the irons by which the uprights are suspended. These plates, which end in screws, are, of course, placed parallel to the posts; at the top a cross-plate unites the screws, on which are washers and nuts. The irons at the bottom of the perpendiculars are similar in character.

When the bow has been completed, the perpendiculars for the centres of the uprights are to be dotted in, and on each side of these half the thickness of the supports is to be drawn. The upper and lower ends of these are, of course, wider than the middle part, the two widths being joined by short oblique lines.

Now, from the points where these oblique lines join the outer to the inner width, and so form a "head," draw diagonals in the interspaces, which will form the centre-lines for the struts. It will be observed that the oblique lines, which form part of the ends of the struts, are at right angles to their sides. It is presumed that this drawing can be finished without any further instructions.

The student is required, in the first case, to draw Fig. 57 to the size of Fig. 58, and then to repeat the whole figure, making

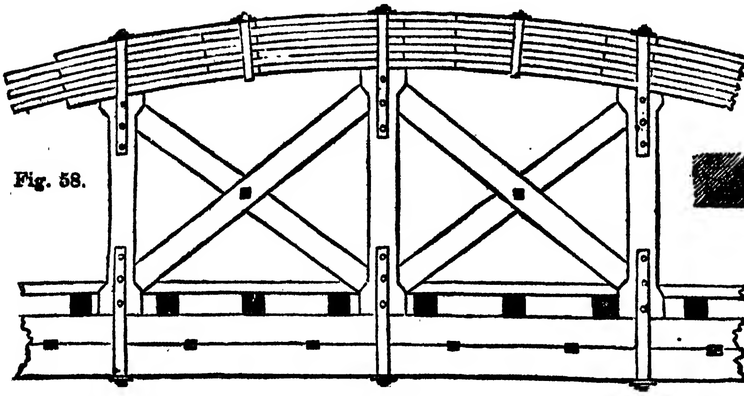


Fig. 58.

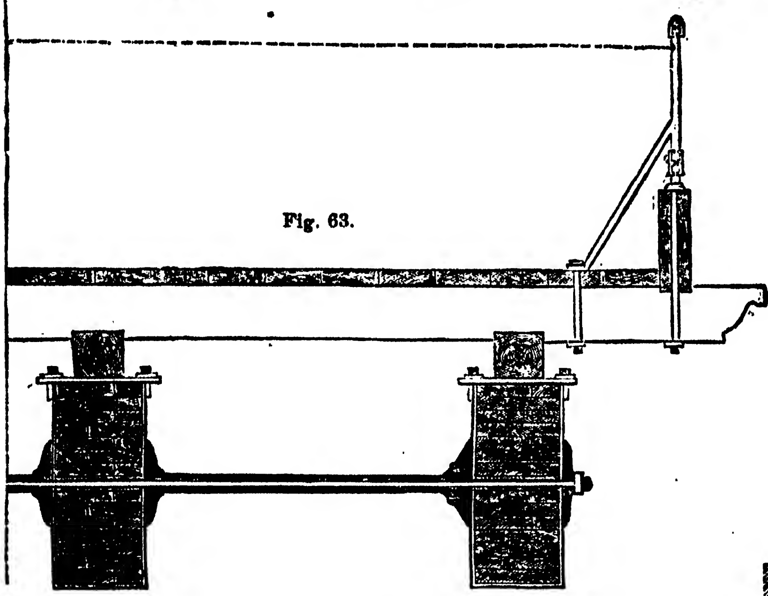


Fig. 63.

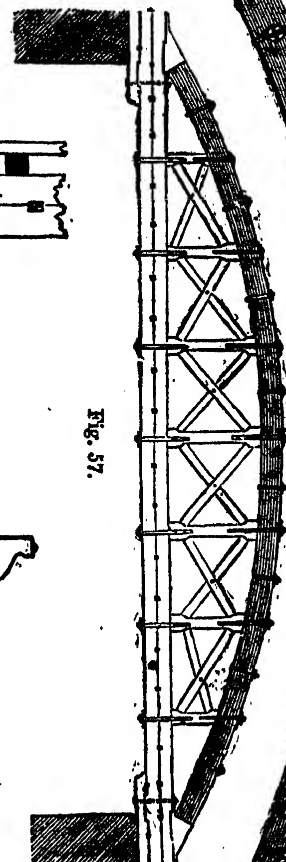


Fig. 57.

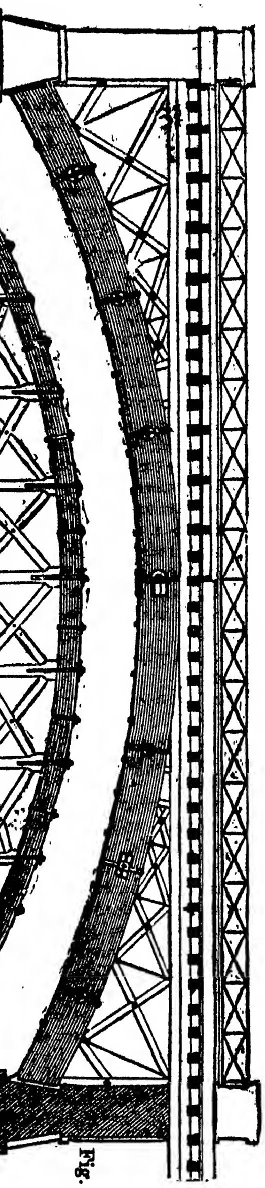


Fig. 59.

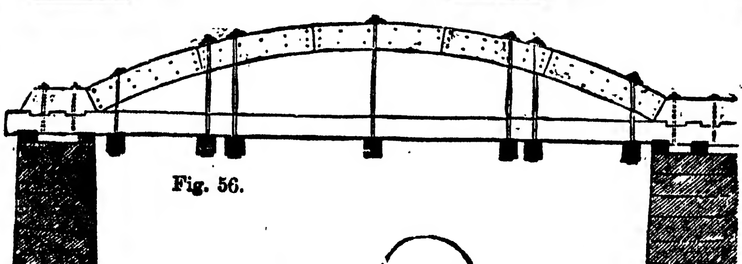


Fig. 56.

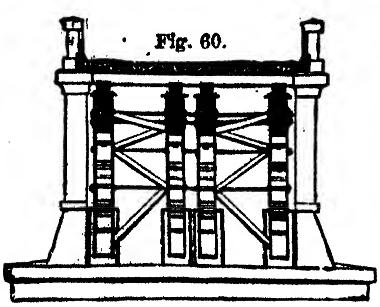


Fig. 60.

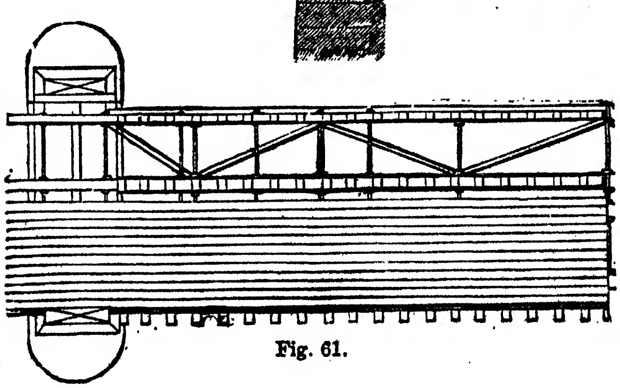


Fig. 61.

Fig. 62.

the drawing on a scale half as large again as Fig. 58. In both of these cases great care will be necessary in drawing the parallel arcs, and the student is reminded of the purpose of the joint in the inking-leg of the compass—namely, so that by bending the leg both nibs may touch the paper, and thus roughness of the edge of the line may be avoided. The lengthening bar will also be needed, and it is then advisable to hold the steel end of the compass in its place with the left hand whilst describing the arcs with the right, for the instrument, thus lengthened, becomes rather unwieldy, and the point is then liable to slip out of the centre.

Fig. 59 is the elevation, Fig. 60 a section, and Fig. 61 a half plan of one of the three arches of the wooden railway bridge from Paris to St. Germain. This bridge is supported *upon*, instead of being suspended *from*, the four arch trusses. These bows are formed of fifteen laminæ, or layers; but not only is the break-joint system carried out in the length, but in the breadth, as will be seen in the transverse section of the bows (Fig. 62). The planks of which the bows are formed are tarred, excepting on the outermost edge; and further, coarse paper saturated with tar was laid between them before binding to the template. When the required curve was attained, the planks were united by strong oak pins, plates of lead being previously inserted to prevent the wood suffering from the stress. The planks are further secured by iron bands, as in the former example. The ends of the bows abut in cast-iron shoes, firmly fixed in the springings of the piers.

Fig. 63 is the half section of the upper portion of this arch, showing the manner in which the four ribs are connected by iron tie-rods, the longitudinal girders, transverse bearers, the flooring, and the hand-rail.

With this knowledge as to the construction of the bridge, the student will not, it is believed, require any information as to the mode of drawing the example, and therefore will be left to apply the instruction he has received in relation to the previous studies.

Fig. 64 is the half elevation of an American timber bridge, by which the Erie Railway is carried over a span of 300 feet. The arch ribs of this structure consist of two separate bows, clamped between cross-timbers, and stiffened by struts placed diagonally.

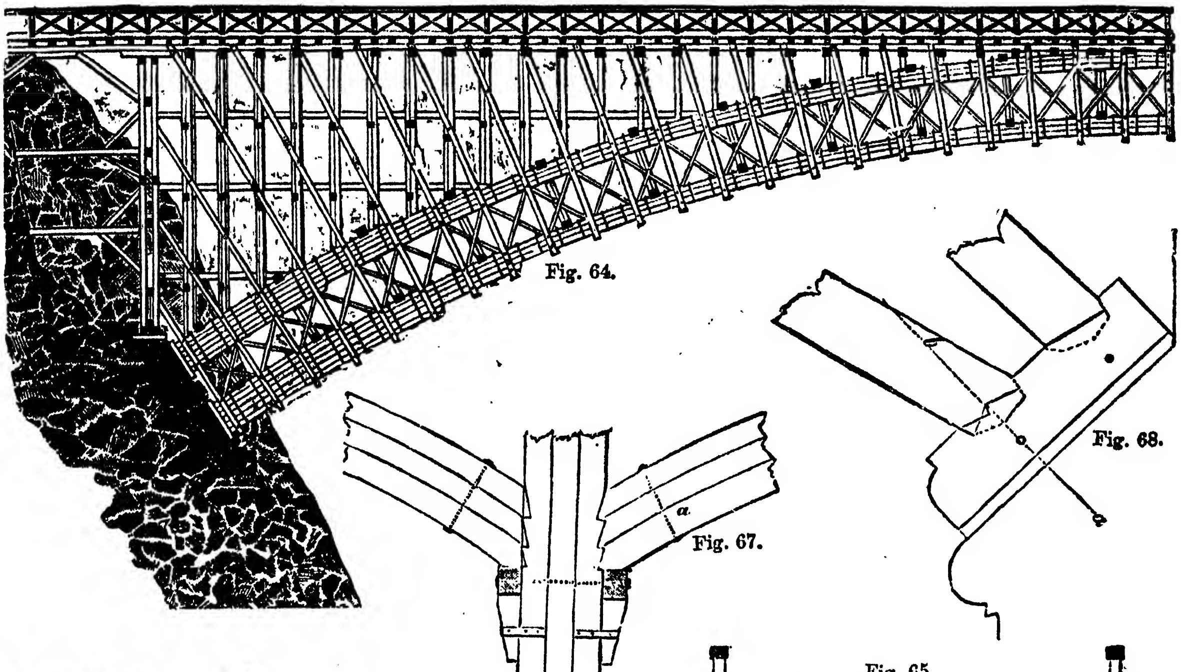


Fig. 64.

Fig. 68.

Fig. 67.

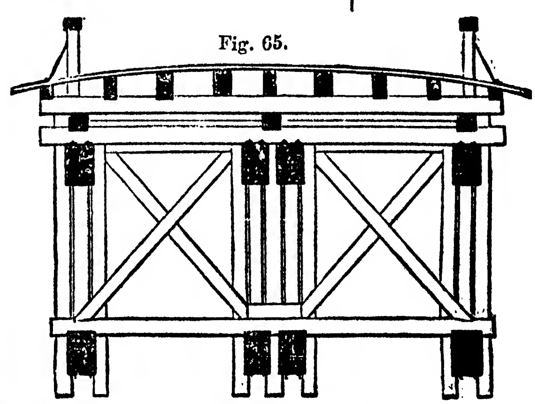


Fig. 65.

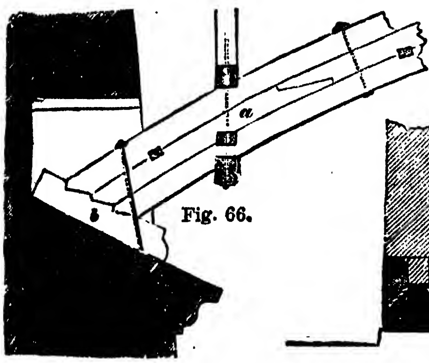


Fig. 66.

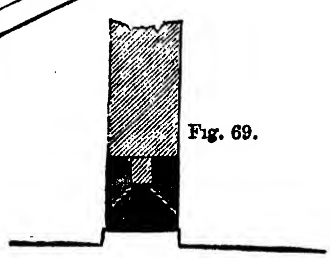


Fig. 69.

The bows are constructed of three layers each, with extra pieces above and below at each end, all being, of course, firmly bolted together. These ribs abut against iron plates attached to the rocks, and support perpendiculars. On these rest transverse beams bearing longitudinal joists, across which sleepers are again placed for the support of the floor-joists of the road.

This construction will be best understood by referring to the section (Fig. 65), from which it will be seen that four such ribs are employed in the bridge, two of which, as in the last example, are placed close together in the middle, the whole being strengthened in a transverse direction by cross-struts.

The longitudinal joists being thus secured on the top of transverse head-pieces resting on the perpendiculars, the bows are

braced up to them by means of straining-pieces clamping these and all the other timbers between them. This is shown in the section, from which it will also be seen that each of the three layers in the bows is made of two timbers, placed side by side, each single bow being thus formed of six square beams in the middle, and twelve at its extremities.

This being the last study connected with bridges, the student is expected to be able to draw it without any instructions, but is advised to copy it on a much larger scale.

Figs. 66, 67, 68, with its section 69, are different methods used in the abutments of bow trusses.

MINERAL COMMERCIAL PRODUCTS.—VII.

EARTHS OF SODIUM, ETC. (*continued*).

Natron, a native sesquicarbonate of soda called *trona*, and mineral soda, is found in sandy soils in Egypt, Mexico, Hungary, etc. Large quantities are collected from the lakes of Sukena in Africa, and chiefly used for native consumption.

Borax, an important article, very useful in chemistry and the arts, is a compound of boracic acid and soda. It occurs in the waters of some lakes in Thibet and Persia, and is imported in an impure state, as *tincal*, from the East Indies. Much, however, is manufactured from boracic acid obtained in a native state by the evaporation of the mineral waters from the extraordinary volcanic lagoons of Tuscany, and from *hayescine*, a borate of lime found in Peru. The annual produce of boracic acid from Tuscany has of late years been about from 1,800 to 2,000 tons.

Saltpetre, *nitre*, or nitrate of potash, is a natural product occurring on the surface of the soil in some hot and dry countries. It can also be prepared artificially, as is done in France, Germany, and other places. The British supply comes chiefly from the East Indies. In 1886 we imported 270,876 cwts., valued at £240,066. Besides being the chief ingredient in gunpowder, it is largely used in chemistry, medicine, and the arts.

Nitrate of soda, or *cubic nitre*, is found native in immense quantities as a geological deposit in Northern Chili and Peru, and is probably abundant over the salt plains of the same continent. It is largely imported by this country; as much as 1,500,897 cwts. being received in 1886 (value £745,940), and is used in agriculture as manure, and for many of the purposes to which saltpetre is applied.

Sulphate of baryta, or heavy spar, is a beautifully crystallised mineral, occurring in mineral veins in Cumberland, Westmoreland, Derbyshire (as cawk), Carinthia, Algiers, and Nova Scotia, and is a spurious substitute for white lead. The minerals *celestine* (sulphate of strontia) and *strontianite* (a carbonate of strontia) are used in the arts for the manufacture of the nitrate of strontia, which is employed for producing a red colour in fireworks. The salts of strontia are remarkable for the red colour which they impart to flame, whilst those of baryta give a green colour. *Fluor spar* (fluoride of calcium) is also a beautiful mineral, and important as the principal natural source of hydrofluoric acid and other combinations of fluorine. It occurs in the lead veins of Yorkshire and Derbyshire, and, from its rich colours, is used in the ornamental manufacture of tazzas of various kinds.

Sulphur is an element existing abundantly in various metallic and non-metallic compounds; but it also occurs native in quantities sufficient to render its extraction from its combinations almost unnecessary; it is, however, separated for economic purposes from iron pyrites. It is found native in all volcanic regions, either as an efflorescence on the surface or largely impregnated with earths. Sicily and Iceland possess it as a volcanic product, and from the former of these countries our chief supply is obtained. Spain also supplies this substance. Sulphur is a very important article as an ingredient in gunpowder. Sulphuric acid (vitriol), so indispensable in the arts, together with other valuable sulphur compounds, has already been referred to. *Graphite*, *plumbago*, or *black lead*, although pure carbon, contains a variable quantity of iron up to a proportion of 5 per cent. It occurs in beds and embedded masses, in fissures in granitic and slate rocks, in nodules in greenstone, and, rarely, in mineral veins. This mineral, well known as the material from which the black-lead pencils of the finest quality are produced, is comparatively rare. It has been found on the right bank of the great river Tungouska, in a country previously little known. In the depths of pine-forests, and at the level of the waters of the wild Tunbusi, torn and abraded by the ice, one continuous mass of graphite has also been traced, 3,000 yards or more in length, with an ascertained depth of thirty yards. The famous mine of Borrowdale is almost exhausted. Considerable quantities are, however, procured from Ceylon and Austria; from Spain, Mexico, Greenland, Cape Colony, and one or two other places is drawn the remainder of our supply. Besides its more common uses, plumbago is of great utility in the manufacture of crucibles or melting pots for metallurgical and chemical purposes.

Among mineral productions available as articles of utility and commerce, mention must not be omitted of some that are of great use in agriculture, especially in such farming as must be carried on in densely-peopled countries, where all qualities of soil must be brought under cultivation. In addition to the silica, alumina, and lime, which are the common chemical constituents of arable soils, there must be a due supply of salts of potash, phosphoric acid, nitrogen, and some other ingredients. Organic remains, in the shape of natural vegetable decay, and of ordinary farm manures, supply these; but mineral manures are also highly valuable and much used. Limes, clays, sands, and marls are all useful under certain circumstances. Saltpetre (nitrate of potash) is a valuable addition to soils requiring nitrogen, but it is costly. The cubic nitre already alluded to exists, however, in great abundance, and is largely available for the same purpose. Phosphates of lime are used to furnish the phosphoric acid. The supply is now chiefly obtained from the small hard nodules of various sizes, composed in part of ancient organic remains (*coprolites*) which are found in the Crag of Suffolk, and in the Greensand at Farnham, Cambridge, Hitchin, Isle of Wight, Havre and other parts of France. Phosphatic nodules are also abundant in the Lias. Thousands of tons of these are annually raised, crushed, and, by the action of sulphuric acid, converted into superphosphate of lime; and they are, in this form, extensively employed as manure. Phosphate of lime is quarried in Spain, and at Sombrero, one of the West Indian isles, and prepared for agricultural purposes.

PRECIOUS STONES.

Important mineral products, on account of their great intrinsic value, are precious stones. These occur in mineral veins, and, as is the case with some of the metals and their ores, in river sands and alluvial deposits brought down from metalliferous districts. Brazil, India, the Ural Mountains, and the mining districts in general, especially those of the older formations, furnish the chief supply. Precious stones are either carbonaceous, aluminous, or silicious. The *diamond* is the only one consisting of carbon, and is well known as the hardest and most valuable gem. Diamonds are prized according to their purity and freedom from colour, or if coloured, according to the depth of the tint. Besides their extensive use for ornamental purposes, they are, in the form of fragments, of much service in the arts—as in glass-cutting, watch-making, and diamond polishing. The aluminous gems comprise the *sapphires* (the red sapphire, or Oriental *ruby*, next in value to the diamond; the blue, or true *sapphire;* the green, or *Oriental emerald;* and the yellow, or Oriental *topaz*); the *corundum*, or adamantine spar, the hardest substance next to diamond, and employed for emery-powder; the *rubies* of various reds; the *topas* of various yellows; and the *garnets*, of which the carbuncle is the choicest. The *emerald*, of a beautiful green, and the *beryl*—yellow, blue, or colourless—are compounds of silica, alumina, and glucina. The most valuable of the silicious gems are the *amethyst*, of a purplish-violet hue; the *Cairngorm* stone, the *opal*, *sardonyx*, *agate* (which is also employed as a burnisher), *chalcedony*, *carnelian*, and *jasper*. The *lapis-lazuli*, from which ultramarine used to be prepared, is a beautiful mineral, found in China, Persia, and Siberia. The *turquoise* may be considered as a phosphate of alumina, lime, and silica, with iron and copper. The chief supply is drawn from the peninsula of Sinai, which appears to have been the great mining district of the ancient Egyptians. The turquoises, so much admired for their beautiful blue colour, occur more or less in veins of sandstone.

With this notice of precious stones we bring our brief account of the Mineral Commercial Products of the earth to an end.

AGRICULTURAL DRAINAGE AND IRRIGATION.—III.

By J. Wrightson, Professor of Agriculture, Royal School of Mines.

CAUSES OF EFFICACY OF DRAINAGE — ACTION OF DRAINS ON THE SOIL — VARIOUS METHODS OF DRAINAGE — CAPILLARY ATTRACTION AND ITS EFFECTS.

The causes of the efficacy of drainage as a means of improving land may be briefly summarised as follows:—

1. Diminished evaporation, rendering the soil warmer.
2. Removal of stagnant water, allowing access to rainfall.
3. The introduction of air, and therefore of oxygen, into the land.
4. Washing of the surface by heavy rains prevented.
5. Improved texture, owing to alternate contraction and expansion of both soil and subsoil.

These causes are followed by good effects readily appreciated by landowners and occupiers. Thus increase in temperature is followed by an earlier and more abundant harvest, by the cultivation of a larger number of plant species being rendered possible, and by greater healthiness in the animals maintained on the farm. Causes 2 and 3 operate in a similar direction, and, in the phraseology of the farmer, "sweeten" the land, while the remaining two causes render manures more efficacious and lasting, and especially the last cause renders the land easier to work and more accessible to the roots of plants. The effects of drainage in improving definite areas of land, and the comparison between the advantages secured and the cost entailed, will be considered hereafter. At present it is only my wish to point out the relation between the causes that occupied us in the last paper, and those practical good effects which alone render the drainer's art valuable.

Our next consideration is the action of drains in the soil. We shall endeavour to come to a truthful conclusion as to the mode in which water is removed by drains. But, before doing so, we must carefully consider the condition of wet soils, the causes of their wetness, and afterwards the effect of introducing a means by which surplus water may be removed. Before proceeding another step, however, it is well to bear in mind that soils are exceedingly various in their textures, and that their relations to water must not be looked upon as constant and invariable. A few simple natural laws account for all the phenomena of drainage, but the action of these laws is modified according to the character of the soil and subsoil, and these modifications occasionally give rise to apparent contradictions in practice. In approaching this subject, it is also requisite to free the mind from false notions as to the action of drains. Thus, too often we hear a drain spoken of as "drawing," as though an underground channel exerted an active instead of a merely passive effect. All idea of *suction* on the part of drains must then be given up, and with it the notion of land being "over-drained." Land may, of course, be over-dry for some purposes; but supposing drains to be multiplied to an indefinite extent beneath the surface, it would be impossible for them to remove more than the *surplus* water of a field. They could not carry off that portion which the varying character of the soil allows it to hold, as a sponge holds a certain amount of water after it ceases to drip.

Soils are wet from three causes—from direct rainfall, from springs, and the soaking down of water from higher grounds. The greater part of our retentive soils are wet from the arrested descent of rain-water as it seeks a lower stratum. Springs usually occur on the sides of hills, and owe their existence to the presence of a bed of clay, or other retentive material, at a greater or less distance from the surface. When rain falls upon a porous soil it sinks in without difficulty, until it meets with an obstruction. Here it accumulates, and may be reached by boring a well down to it. Supposing, however, that this obstruction, probably clay, crops out upon a hill-side at no great distance, there you will have springs. As soon as the water rises in the natural reservoir until the lip of the basin is reached, it will overflow, and cause wetness in the land immediately beneath it. Again, water may find its way from the point at which it fell, and incommode land more or less remote by a slower soaking process, in which definite gushing springs do not occur. This is usually met with in free soils, and is defined by Mr. Bailey Denton as that moisture which is caused by water of distant and adjacent higher ground pressing up through free soils of a lower level, and which may be called "diffluent water."

Now the treatment of land wet from these three causes has given rise to two distinct methods of drainage: one in which the drainer effects his purpose by means of pipes laid at regular intervals, adapted to soils suffering from the first kind of wetness; and another in which the object of the drainer is rather to attack the source of water and cut off the supply, than to attempt to drain by regular channels at stated distances apart. The first method is identified with Mr. Smith, of Deanston; the second with the name of Elkington, who flourished in the latter half of the last century.

The principle upon which Elkington's system of draining was based will be rendered more intelligible when his practice is described. It is evident, however, that it is only under peculiar conditions of soil and subsoil that it can be effective. It is comparatively seldom that the source of wetness can be localised so as to allow of its removal by a single drain, and although such cases occur, yet, more ordinarily, land is wet because the rainfall is prevented from finding its way through the soil to depths at which it would be harmless to growing plants.

Let us, then, investigate an ordinary case. A field is wet, and requires draining. It is wet simply because the water cannot escape, and this may be due to general retentiveness throughout the mass, as is the case in clay soils; or to an obstructing bed at some little distance beneath the surface. Taking the first case, we are at once introduced to the difficult question of the action of drains in stiff clay soils. That water will penetrate such soils has been proved, as Mr. Morton has tersely observed, by the fact that they are wet. Their power of retention is, however, very great, and this is a force which, while it exists, cannot be overcome by any number of drains. Clay soil will hold, according to the experiments of Schübler, 48 pounds of water per cubic foot, and it is only the excess over this amount which would find its way into a drain. When, however, such soils are furnished with a series of underground channels, and when the work of the drainer is supplemented by deep cultivation, the character of the soil is gradually altered. The continuity of the soil is broken, air gains access, pulverisation takes place, and the altered soil becomes amenable to the ordinary rules which govern more usual cases. Vigorous treatment is, however, requisite, and no system of wide intervals between drains would be successful. The drains must be close enough to exert what Mr. Bailey Denton has termed a reciprocating effect upon one another, that is, so close that the action of one shall extend into the region of action of its neighbour. After the full effects of thorough drainage have been brought to bear upon a clay soil, the water will pass through it and find its way to the drains in the same manner, but never with the same facility, as in lighter soils. Let us, then, turn to the case of a more porous soil, wet from direct rainfall.

Here we must suppose a definite obstruction to the downward passage of water. The water tends to pass through the soil in straight lines, according to the law of gravity. It meets with the obstruction, and begins to rise upon it towards the surface. There is no limit to its rise. It may form a lake, or it may be the cause of a marsh. In other cases it will not rise to the surface, but form what is known as a "water-table" one, two, or more feet beneath.

Now this water-table, or level of supersaturation, is not the limit of wetness. Over it is a stratum of greater or less thickness, depending upon the character of the soil, wet from capillary attraction; and if this force raises water to the surface, the land requires draining. Capillary attraction may be defined as a triumph of adhesion over cohesion and gravity. When a piece of wood or metal is dipped into water and withdrawn, its wetness may be explained by the fact that the adhesion of the liquid to the object introduced is stronger than its cohesion to the remaining water it has left, or to the downward force of gravity.

A similar attraction is exerted by the soil and many familiar porous substances when placed in contact with water. The superior force of adhesion lifts a tiny column of water through the interstices of the porous material presented until the weight of the column thus lifted counterbalances the attraction of adhesion, and the limit of the force is reached.

A healthy soil should have a layer of earth at its surface a few inches in thickness, which must not be continually wet

even from water raised by capillary attraction. It will be readily seen that if such a layer does not exist, capillarity and evaporation will between them lower the temperature of the soil considerably. Growing plants will also suffer from the same causes which render saucer-watering, in the case of potted plants, objectionable. It is, indeed, a case closely analogous to saucer-watering, and the sooner it is altered the better for the crops. The question as to the height to which soils will thus lift water has been assumed and guessed at; but data of a precise kind are still needed. A few years ago I undertook a series of experiments for the purpose of throwing light upon this point, and the results obtained were as follows:—When air-dried clay or sand is placed in a tube, one end of which is immersed in water, the fluid rises rapidly, especially in the case of sand. Thus, twenty minutes after the experiment was commenced, the fine sand was wet 9 inches above the level of the water in the saucer, and seven hours after it was wet 15 inches up the tube. Clay, in a finely-powdered state, had during this time only raised water 3 and 5 inches in height, taking two tubes containing similar soils. The capillary power of the sand was, however, almost exhausted in this short period, and although the experiment was conducted for 132 days the column of water was never raised higher than 23 inches. The clay behaved very differently. Although water rose slowly, it rose very steadily, and at the termination of the experiment, 132 days after its commencement, it was wet 35 and 33 inches, taking again the results of two tubes. During the last six weeks of the experiment the rise was exceedingly slow, and only 1·8 inch of extra height was obtained. As this was partially due to the upper soil becoming wet by evaporation and condensation of water from the part wet by the force of capillarity, the limit of the force was considered to have been reached, and we may, therefore, take 3 feet as the height to which water may be raised by clay in a fine state of division. There was one more point worthy of attention in these experiments, namely, that a precisely similar soil to the clay just mentioned, but in a somewhat coarser state of division, was only able to lift a column of water 15·5 inches, showing that physical condition even more than material is an important constituent in this power possessed by soils.

It is the object, then, of the drainer to so lower the water-table that a thin layer of dry soil may intervene between the surface and the portion wet by capillary attraction.

A drain is constructed, say four feet beneath the surface, and immediately water flows from it, the water-table begins to sink, until it is on a level with the bottom of the drain, just as the water in a cask would sink to the level of the lowest portion of a hole made through the wood. Remembering that water falling on the surface makes its way down through the soil as straight as possible, it is evident that rain feeds the water-table, constantly tending to raise it; but as the water-table will have a difficulty to rise higher than the drain, it will be seen that the water, for the most part, enters the bottom, and not the top of the drain. It can only enter the top when, by heavy rains, the water-table is unnaturally raised; but on the return of ordinary weather the lowest portion of the draining tile will once more become the upward limit of the saturated portion. The area over which one drain will act is, of course, very limited, and the limits of its action are soon reached. The water-table, although kept down to the level of the drain in its immediate proximity, just as a river keeps down the water-table of a district through which it passes, yet rises as we recede from the drain until it extends to a point completely out of its influence. Hence a series of drains is required so near to each other that the level of supersaturation is sufficiently lowered throughout the intervening space. It is generally believed that the action of drains is intensified by the near proximity of other drains. This is mostly owing to the aëration of the soil. A bed of sand or gravel underlying a clay soil will not drain the field, although such a gravel bed may be looked upon as a continuous drain, or means of escape for water. Under such circumstances, however, a few drains placed at wide intervals would bring the drying power of the porous bed into immediate action by the admittance of air, and the field would be easily and effectually dried. It is, indeed, surprising to what distances drains, under such circumstances, will draw. Instances are not wanting in which the channels have been effective at sixty yards apart. Such cases at once lead us to the consideration of the means of draining employed by Elkington and other drainers, and introduce us to the more purely practical part of our subject.

BUILDING CONSTRUCTION.—V.

BRICKWORK.

Bricks may be considered as artificial stones, and seem to have been used from a very early period in the history of man. Their average size in England is a trifle less than nine inches long, four and a-half inches wide, and two and a-half inches thick. Their uniformity in size enables builders to describe the thickness of walls by the number of bricks extending across it; thus, a slight brick partition wall being formed of bricks lying on their broad side, with their length in the direction of the length of the wall, is called a "half-brick thick," its thickness being four and a-half inches; a wall in which the length of the brick extends through the thickness is called a "one-brick thick;" a wall 14 inches through is called a "brick and a-half thick" (though to speak more accurately it would be 13½ inches, that is, 9 for the whole brick and 4½ for the half); an 18-inch wall is said to be a "two-brick thick," and so on.

If we suppose a wall of only half a brick thick, all the bricks used would, of course, be laid lengthwise, so as to show their whole length in the face of the wall. In laying a second course of bricks, care would be taken to prevent any two vertical joints from coinciding. This would be effected by placing the joints or meeting of the ends of the bricks forming the second course over the middle of the bricks of the course below. This arrangement would be attended to in all the succeeding courses, and is technically called *breaking joints*: a wall thus built is said to have a proper *bond*, a term which implies that the parts are well connected.

It must, however, be remarked, that the above supposition of a building only half a brick thick has been introduced merely to illustrate the principle of what is technically called *bond* in building; no brick wall so slight as the above should ever be used, this dimension being much too weak to afford proper stability even to the smallest buildings, unless the brickwork be held together by wooden framing, of which it fills the vacant spaces. This style of work, used for economy, is altogether unsuitable for public buildings, unless of a temporary nature, and is called "*brick nogging*," of which specimens are very common, especially in villages. Brick nogging is also sometimes used for the partitions of dwelling-houses.

It is important that brick walls should be kept perfectly vertical; and it must be remembered that if a wall at the bottom is in the slightest degree "out," the evil (like every other) will go on increasing, the top will gradually extend beyond the foundations and fall. But this is not all; the wall must be kept "plumb," which does not necessarily mean upright, but a straight surface; thus, a wall may be slanting, as against a bank, or the side of a tower which tapers towards the top; but in whatever position it may be, it must be kept plumb; and the plumb-rule* may not only be used for this purpose, but to keep the vertical joints regularly over each other. This is generally termed "keeping the *perpends*." Next in importance to this, or we may say *equal* to it, is the subject of *bonding*. By *bond*, is meant that method of combining the bricks that each individual may be supported by as many others as possible; and this is done by the judicious arrangement of the joints, which will be seen on reference to the annexed illustrations.

Fig. 9.

* A *plumb-rule* is a straight piece of wood, to which is attached a string with a plummet or lump of lead. The name is derived from the Latin word *plumbum* (lead), and the line formed by the weighted cord, when perfectly still, is a true *vertical* line.

Let us suppose that an attempt were made to build a wall as in Fig. 9, viz., by placing rows of bricks over each other: it will be evident that here none of the stones receive any other support than is afforded by those immediately under them. Thus A is supported by B, C, D, and E, and this is the greatest amount of support it could receive; nor would it be less liable to sink (supposing the ground to give way under it), even if it rested on a greater number of bricks so disposed, for in case of failure in the foundation, the whole column A B C D E would sink, sliding down at the side of F G H I J.

Now let us turn to Fig. 10. Here, by the simple arrangement of "breaking joint," we get the brick A supported by *two* others, B and C; these rest on *three* bricks, D, E, F; which in their turn are supported by *four*, G, H, I, J; and these again rest

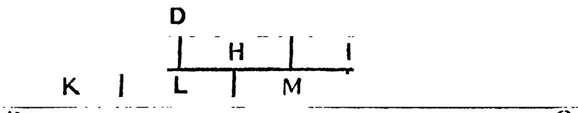


Fig. 10.

on *five*, K, L, M, N, O. Thus the brick A is supported by *fourteen* others, and its foundation rests on the entire space extending from P to Q; further, this breadth of foundation does not refer to this brick only, but to *every* individual one composing the wall: thus, *r* rests on C, *s*; E, F, *t*; H, I, J, *u*; and L, M, N, O, *v*; and any brick taken promiscuously is similarly supported; thus D rests on G, H, and G, H rest on K, L, M, etc.

In this illustration all the bricks are supposed to be laid on their broad sides, with their length parallel to the front of the wall; in this position they are called *stretchers*. When bricks are laid so that their *ends* are towards the surface, and their length extends into the thickness of the wall, as in the group shown in Fig. 11, they are called *headers*.

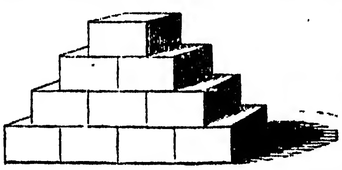
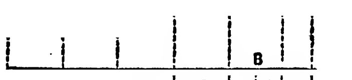


Fig. 11.

Now, on referring to the previous diagram (Fig. 10), it will be seen that the wall there represented would be a "half-brick thick" one; and that even if we were to build one three times as thick on the same system, the wall would consist of three separate ones of half-brick thickness each, *neither having any connection with the other;* and thus the front might fall forward, the

Fig.



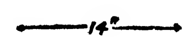
g. 12.

Fig. 15.

Fig. 13.

hindermost one might fall backward, or the middle one might sink; for neither one would give any support to the other, not being in any way *built* in to each other, the bonding being merely longitudinal or *lengthwise*, but no *cross* bond existing between them. Combinations of stretchers and headers have therefore been devised, by which the entire thickness of the wall is so bonded as to form one compact structure. Thus, in the one system called "English bond," one course of bricks

Fig. 17.



16.

Fig. 18.

is laid lengthwise, or as stretchers; and the next crosswise, or as headers.

The annexed illustration (Fig. 12) shows the commencement of a wall of one-brick thickness, built in what is called English bond. In this it will be seen that the one course consists entirely of stretchers, and the other entirely of headers. The plan of the lower course (Fig. 13) is given below the elevation, and the plan of the upper course (Fig. 14) is placed above it.

Now bricks are exactly half as broad as they are long, and thus, if when the first course of stretchers had been laid, we followed the simple idea of placing the next course as headers, and commenced at A (Fig. 12), we should not produce a bond at all, for the second header, B, would fall over the end of the first stretcher at C; thus one joint would be immediately over another; and of course, if this were carried up, one portion of the wall would soon separate itself from the other. The bricklayer, therefore, having laid his lower course, places D, his first header, at A; he then cuts a brick in halves *lengthwise*, and lays this half-brick next to the stretcher. This is called a "closer," E. He can after that proceed to lay the headers regularly, for the next header, F, will then be placed so that half of its width will be on each side of the joint C. Then will follow another header, G, which will leave a quarter of the length of the stretcher exposed, and this will be covered by the next header, H, which will overlap the joint by half its width.

Fig. 20.

Fig. 21.

Fig. 22.

Fig. 15 shows the end of the wall which has been described.

Fig. 16 illustrates a 14-inch or "brick and a-half" wall. The elevation is the same in this as in the last; for of course the *thickness* of a wall is not visible on its surface; the plans, however, show how the bonds are arranged.

Fig. 17 shows the plan of the first course, and all alternate

courses above it; in this it will be seen why the wall is called "brick and a-half."

Fig. 18 is the plan of the second course, and the alternate courses above it; and Fig. 19 shows the end of such a wall.

Fig. 20 shows the end, and Figs. 21 and 22 are the plans of a two-brick thick wall, built in old English bond, and from these it will be seen how the thickness is made up. In the

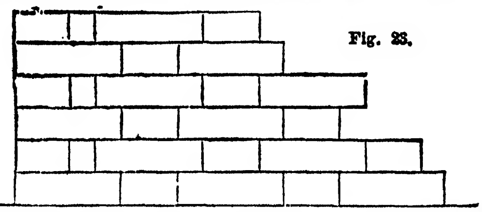


Fig. 23.

lower course, there is a row of stretchers on each side, between which headers are placed; thus the thickness is made up of the widths of two half and one whole bricks, whilst in the upper course two headers laid transversely to the face of the wall give the required width. The dotted lines on each of these plans show where the joints would fall when the one course should be worked over the other.

In copying these examples, the student is advised to work to a scale, so that the bricks and half-bricks may be drawn in their proper proportion; and it may be well to state here

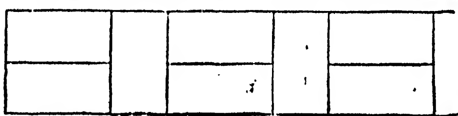
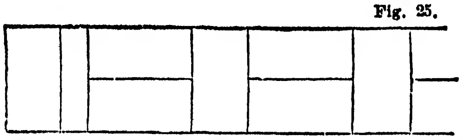


Fig. 24.

Fig. 25.



that this plan is desirable in working all the exercises in these lessons; for if every line be simply measured, the studies will not convey all the instruction intended, whilst by working them to a larger scale they will afford excellent practice. The student is also advised to attempt simple colouring from the commencement, so that the use of compass, pencil, and brush may be practised together.

Another kind of bond in very general use is that called "Flemish bond."

This consists of stretchers and headers laid alternately in the same course. Fig. 23 is the elevation, and Figs. 24 and 25 are

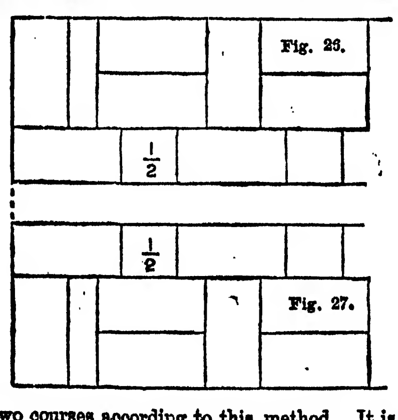


Fig. 26.

Fig. 27.

plans of two courses according to this method. It is neater in appearance than the English bond; but, owing to there being less headers in it, the cross bonding is not considered to be as strong. In walls of almost all thicknesses above nine inches it is often necessary to use half-bricks, in order not to break the longitudinal bond; but although uniformity in the bond on the surface may be thus preserved, it is at a sacrifice of the cross-tie. It must be taken as a rule, therefore, that *a brick should never be cut, if by any skill on the part of the workman it can be laid whole;* for when a brick is cut, an extra joint is created

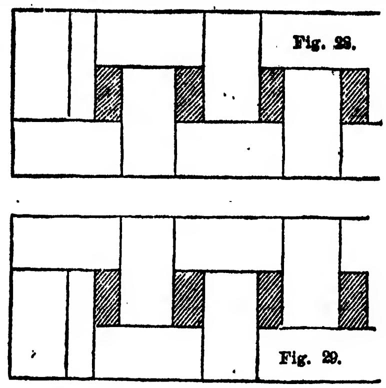


Fig. 28.

Fig. 29.

in a structure, in the erection of which the greatest difficulty arises from the great number of joints. The utmost care, then, should be taken to avoid making more than are absolutely indispensable.

Figs. 26 and 27 represent plans of first and second courses of a brick and a-half wall, built in Flemish bond.

Figs. 28 and 29 show plans of the same wall, built so as to avoid the half-bricks without interfering with the strength of the bond. This, however, leaves an open space on each side of the header in the thickness of the wall, which may either be filled up with a bat or left open.

ANIMAL COMMERCIAL PRODUCTS.—V.

III.—STEARINE AND OILS.

THE chief supply of animal oil is derived from various species of seals (order *Carnivora*, family *Phocidæ*) and whales (order *Cetacea*).

In order to meet the needs of the creature it defends, the true skin of whales is modified, forming the layer of blubber, called by whalers the blanket, probably in allusion to its office of preserving the animal heat. The blubber is composed of a number of interlacing fibres, capable of containing a very large quantity of oily matter. The thickness of the blubber varies in the several species; those inhabiting the frigid zones have it of greater thickness than those which habitually live in warmer seas. It is never less than several inches, and in many parts of a whale is two feet deep, and, moreover, as elastic as caoutchouc, offering an admirable buffer to the force of the waves and the pressure of the water, as well as a defence from cold. In a large whale the blubber will weigh thirty tons.

The species of whales that are regularly hunted for the sake of their oil are—

The *Greenland Whale* (*Balæna mysticetus*), which is confined to the Greenland and Spitzbergen seas, its migrations being regulated by the extent of the perpetual ice.

The *Hump-backed Whale* (*Megáptera longímana*) attains a length of sixty to seventy feet, and inhabits the Greenland seas, where it is found in great abundance. Though its oil is said to be superior to that which is furnished by the Greenland whale, and not much inferior to the oil of the sperm whale, yet it is not eagerly sought after.

The *Pike*, or *Finned Whale* (*Balænoptera rostrata*) is a native of the seas that wash the shores of Greenland, and is sometimes seen near Iceland and Norway. The flesh is in some repute as a delicacy among the natives of these northern regions. The oil which it furnishes is said to be particularly delicate.

Sperm Whale (*Cátodon macrocéphalus*).—This species, which measures from seventy to eighty feet in length, is chiefly notable on account of the valuable substances which are obtained from its body—oil, spermaceti, teeth, ambergris. It differs from the true whales in having no baleen plates in the

palate, but from forty to fifty conical teeth in the lower jaw, which fit into cavities in the upper, so that the mouth is capable of being completely closed. The head is of an enormous size, forming about one-third of the entire length of the animal. It is cylindrical, truncated, not composed of bone, but of a sort of cartilaginous envelope, containing an oily fluid, which hardens by exposure to the air, and is then known as *spermaceti*. This substance is also diffused through the blubber.

The sperm whale, or cachalot, is generally distributed in all seas, but principally in those of the southern hemisphere.

The oil is obtained from the blubber, which is only fourteen inches in depth on the breast, and eleven inches on the other parts of the body, and is therefore not so abundant in proportion to the size of the animal as that which is extracted from the Greenland whale. Its superior quality, however, compensates fully for its deficiency in quantity. It is much used for burning in lamps.

The spermaceti from the head is very valuable as an ointment, and for the manufacture of candles. The United States fit out more ships than any other nation for this whale fishery, bringing home annually more than 200,000 casks of train oil, and 150,000 casks of spermaceti. Next to the United States, England is the country most engaged in the whale fisheries, the principal port, Hull, having about 200 ships. France employs 145 ships in this business, the principal port being Havre. Norway, Sweden, Denmark, and the Hanseatic Towns take some part in the whale fisheries, though not to any very great extent.

Spermaceti candles are mostly manufactured in England. Spermaceti is imported in considerable quantities from the United States.

The *Beluga* (*Beluga catodon*), also called the white whale, on account of the colour of its skin, is an inhabitant of the higher latitudes, being found in great numbers in Hudson's Bay and Davis's Straits, and frequenting the mouths of large rivers on the northern coasts of Asia and America. The oil furnished by the beluga is of very good quality, although small in quantity, and is sufficiently valuable to have led to the establishment of regular beluga hunts in the great North American rivers, which they ascend for some distance in search of prey. The skin can be made into a peculiarly strong tough leather, and is said to resist an ordinary musket-ball.

The *Seals*, which have been described in page 74, are also hunted for the sake of their oil; and the pursuit of them is superseding that of the Greenland whale, for the latter has been greatly reduced in numbers by continued persecution at the hand of whalers for upwards of one hundred years past.

A large number of British vessels are engaged each year in the capture of whales and seals: and the importation of train or blubber oil and spermaceti exceeds 15,000 tuns a year. The products of whaling vary very much in quantity, owing to the precarious nature of the employment.

Tallow.—This is an article of great commercial value. It is animal fat separated from membranous matter by fusion, and consists chiefly of stearine, with a small quantity of oleine. It is manufactured into candles and soap, and is extensively used in dressing leather, and in various other processes in the arts. We are supplied extensively with native tallow, and we annually import a large quantity, principally from Russia, France, the United States, the South American Republics, and the British Colonies. Our imports of tallow from Australasia and the Argentine Confederation were in 1886, 442,102 cwts. The entire imports from all parts of the globe into Great Britain and Ireland exceed 50,000 tons a year.

The tallow we receive from Australia is chiefly obtained from sheep, the carcases of which are boiled down for this product alone; that from South America is from oxen and even horses, which roam in a half-wild state over the grassy plains of Monte Video, La Plata, etc. The animals are slaughtered for their hides, tallow, and bones.

IV.—FOOD PRODUCTS.

Butter is extensively made in the counties of Cambridgeshire, Suffolk, Yorkshire, Somerset, Gloucestershire, Oxfordshire, and Essex. In Scotland excellent butter is made in Clydesdale and Aberdeenshire. The butter produced in Great Britain is, however, insufficient for home consumption, and large quantities are imported, principally from Ireland, where it is a staple commodity; and from Holland, Belgium, the Hanse Towns, France, and the United States. The foreign imports for 1886 were 1,509,275 cwts.

Cheese is the curd of milk compressed into solid masses of different sizes and shapes, salted and dried, and sometimes coloured and flavoured. Besides our own supply of Gloucester, Wiltshire, Cheshire, and Stilton cheeses, which are the most in demand, we import a considerable number of foreign cheeses, amongst which are Limburg cheese from Belgium, Swiss cheese from Switzerland, Parmesan cheeses from Parma and other places in Lombardy, American cheeses from the United States, Edam and Gouda cheeses from Holland, and German cheeses from Westphalia. The last come to market made up into round balls, or short cylinders, under a pound weight each.

The rich flavour of Parmesan cheese is owing to the aromatic plants which abound in the Italian pastures. Stilton cheese, so named from the town in Huntingdonshire where it was first brought into notice, is the dearest of all English cheeses, the price being generally to that of Cheshire as 2 to 1, or 2 to 1½. To produce premature decay, and consequently an appearance of age, in these cheeses, the manufacturers are said to bury them in masses of fermenting straw; also to spread the curd out on the ground over night, by which it becomes sooner liable to the blue mould. The quantity of cheese of all kinds imported during the year 1886 was 1,734,890 cwts., valued at £3,871,359, the principal countries which supplied us being Holland and the United States.

Lard.—The melted fat of swine is imported chiefly from the United States. In 1886 we received 895,462 cwts., value £1,544,632.

LIVE STOCK.

Oxen.—The numbers imported were—in 1886, 241,360, valued at £4,358,868; whereas in 1867 the numbers were only 177,948. The average price per head in 1867 was £17 19s.; and the principal countries whence imported were Schleswig, Holstein, and Holland.

Sheep and Lambs amounted, in 1865, to the number of 914,170; in 1886 to 1,038,965, valued at £2,010,194.

MEATS.

Bacon and Hams.—The imports in 1863 were as much as 1,877,813 cwts., after which year the importation declined; and in 1867 the number of cwts. was only 537,114. After 1870, however, it began to rise again, reaching 4,210,829 cwts. in 1886, valued at £8,402,828.

Beef (salted).—The imports were, in 1867, 246,767 cwts., of the value of £628,802; in 1886, 190,723 cwts., valued at £316,393.

Pork (salted, not including hams).—The quantity which was received in 1867 was 150,285 cwts., of the computed real value of £351,871; in 1882, 266,259 cwts., and in 1886, 290,691 cwts., valued at £431,245.

Preservation of Meat.—How to meet the growing demand for butcher-meat, consequent on an increase of population and a decrease of stock, arising in great measure from pasture-lands being brought under tillage, is a question of grave importance in relation to the commercial prosperity of this and other countries, and calls for the earnest attention of legislators and scientific men. Though the stock of sheep and cattle raised in England is large, and that of cattle in Ireland and Scotland is a source of wealth to those two countries, yet enormous quantities of meat are imported. For years past, in Australia and the Argentine States, we find that the flesh of cattle and sheep has been sacrificed for other parts of the animal; recently, however, many methods have been devised by which meat can be economically imported into this country, and these methods have been hailed with satisfaction by the public at large. The importation of the living animals, at one time considered altogether out of the question, is now carried on to a considerable extent, and great success has attended some of the processes by means of which the meat can be preserved in a fresh state a sufficient length of time to admit of its transportation from distant regions.

This art of preserving meat is one of modern times, and differs entirely from the old and common methods by means of salt, saltpetre, sugar, etc. These substances, when in solution,

do not absorb oxygen, and therefore they prevent decomposition. The history of the art of preserving meat in a fresh state is associated with the earliest Arctic explorations. Scientific observers found that scorbutic diseases arising from living exclusively on salt meat were fearfully aggravated by extreme cold; the Admiralty, therefore, offered inducements to merchants to devise plans for preserving unsalted meat, cooked or in a raw state, thus doing away with the use of salt meat altogether. It is hardly possible to over-estimate the importance of this subject, as is evident from the fact that preserved provisions, cooked or raw, are an absolute preventive of sea scurvy.

M. Appert, a French gentleman, was the first to succeed in the attempt to preserve unsalted or fresh meat, and in 1810 he received a prize of 12,000 francs from the Parisian Board of Arts and Manufactures. In the following year, M. Durant, a colleague of M. Appert, took out, in Great Britain, a patent, which was subsequently purchased by Messrs. Donkin, Hall, and Gamble, for £1,000.

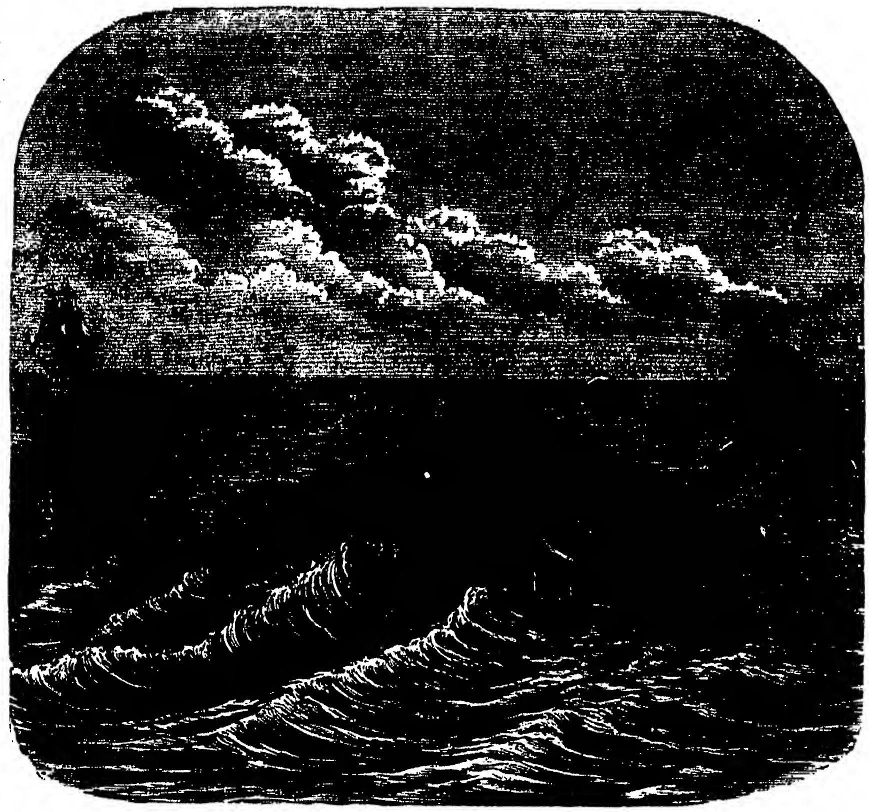
M. Appert's process consisted in partly cooking the meat, placing it in a glass vessel in a bath of chloride of calcium, heating it to about 240° Fahr., and then hermetically sealing the lid. Appert's plan, as adopted and improved by Messrs. Donkin, Hall, and Gamble, is as follows: — Tin canisters are substituted for the glass vessels, and the meat (previously parboiled) is placed in them, with a rich gravy or soup. The lids, are pierced with a small hole, are then soldered down air-tight, and the canisters immersed in a bath of brine or chloride of calcium, heated to boiling point. On the steam issuing from the hole in the canister lid, it is suddenly condensed by the application of a cold wet rag, and a drop of molten solder being dexterously applied to the hole at the same moment, the case becomes hermetically sealed. On cooling, the ends of the canisters are slightly concave, from the effect of atmospheric pressure, if the process has been successful; but if the ends have flattened, or become convex instead of concave, then either the case has not been properly soldered, and is not air-tight, or the meat has decomposed and liberated gases.

As soon as this modification of Appert's process was made practically perfect, it was tested by order of the Admiralty, and ships were dispatched by them to the Arctic regions with an abundant supply of these meat canisters. On their return, the officers in command of the expedition reported favourably of the whole. Their value in cold climates having thus been clearly demonstrated, the experiment was tried with equal success by vessels trading in the tropical regions. For ship use these preserved meats are invaluable, and hardly a vessel now leaves Great Britain without a supply. In India they are extensively used as luxuries in the towns, and as necessaries in the remote districts, where fresh meat of any kind is scarce and bad. It may be noted here that most of the ocean steam-ships belonging to ports of the United States and Europe are provisioned with fresh meats conserved in ice.

V. WOOL.

In commercial phraseology the term "wool" is applied to the hair of the alpaca, goat, beaver, and rabbit, and to allied substances; but, more strictly speaking, it belongs to the sheep alone, the hair of which, from time immemorial, has been woven into cloth.

Wools are divided into two great classes—clothing wools and combing wools, or short wools and long wools; and the fabrics woven from them are termed woollens or worsteds, according as the one or the other is employed. The fibres of clothing wools felt or interlace with one another, forming thereby a dense compact material, suitable for warm and heavy clothing; these wools are manufactured into broad cloths, narrow cloths, felt for hats, blankets, carpets, serges, flannels, and tartans. Combing wools, on the contrary, though long in fibre, do not felt, and are therefore employed in the manufacture of light and loose, such as stuffs, bombazines, merinos, hosiery, camlets, and shawls, and various mixed goods, as damasks, plushes, and velvets.



THE SPERM WHALE (CATODON MACROCEPHALUS).

The wool of the sheep has been greatly improved since the animal has been brought under the fostering care of man. The *mouflon*, which is considered by some zoologists as the parent stock of the common domestic sheep, inhabits the mountains of Sardinia, Corsica, Greece, Barbary, and Asia Minor. This animal has a very short and coarse fleece, more like hair than wool. When domesticated, the rank hair disappears, and the soft wool around the hair-roots, which is hardly visible in the wild animal, becomes singularly developed. If sheep are left to themselves on downs and moors, there is a tendency to the formation of this hair amongst the wool; its occurrence in the fleece of domestic sheep is therefore rare, and is always regarded as proving defective sheep-farming.

The climate of Great Britain is unfavourable to the growth of the best wools; hence the superiority of the Merino, Saxony, and Australian wools, the produce of countries having a higher average temperature.

THE

By J. M. Wigner, B.A., B.Sc.

SUPERHEATER (*continued*)—LOCOMOTIVE BOILERS—ARTIFICIAL DRAUGHT—CONSTRUCTION OF BOILERS—MANHOLE—BLOW-OFF COCK—GAUGE GLASS, ETC.

In some forms of superheater the steam passes through a set of pipes arranged in a chamber, through which the smoke and heated air pass on their way to the chimney. In other varieties the smoke is made to traverse a series of small tubes, while the steam passes outside them. This plan was adopted in the *Great Eastern* steamer, the steam-pipe opening into a large rectangular chamber, placed at the foot of the chimney, and traversed by a large number of vertical tubes through which the smoke had to pass. The area of the superheater varies, of course, very considerably; but a common proportion is about one and a-half square foot of surface for each nominal horse-power of the engine. A somewhat similar arrangement is sometimes made in tubular boilers, vertical tubes being introduced,

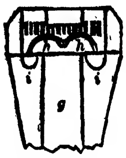


Fig. 6.

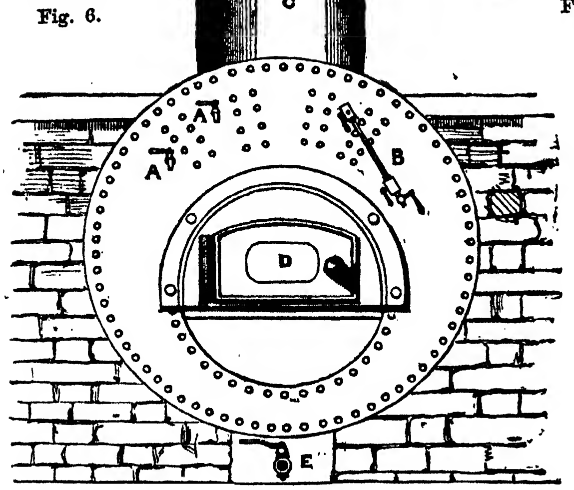


Fig. 10.

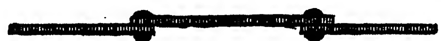


Fig. 7.

Fig. 8

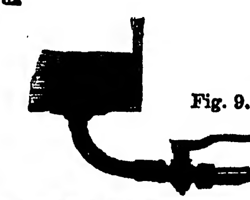


Fig. 9.

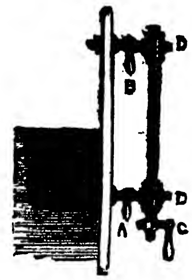


Fig. 11.

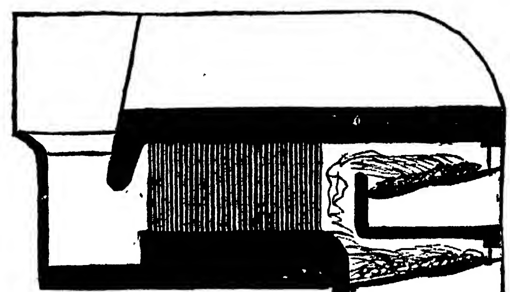


Fig. 5.

which are filled with the water, while the smoke finds its way between them, and thus imparts its heat to their outer surfaces, instead of their inner surfaces, as is usual.

This plan was suggested by the Earl of Dundonald, and in Fig. 5 we have an illustration of its use. This figure shows a section of the boilers of the *Atlantic* steam-ship. Two furnaces are employed here, one being placed above the other; the smoke from the two unites, and, after passing in and out among the vertical tubes, strikes against the bridge at the further end, and thence escapes into the chimney.

We must not stay here to notice the many other modifications often made in various marine boilers; for these, and all other details, the practical student should consult Bourne's various works on the subject, in which he will find almost every variety figured and described, and in many cases full details as to dimensions and heating surface, for the particulars of which we cannot find space.

Locomotive boilers differ in some respects from any of those already described. Instead of being built and fixed in a given place which they are permanently to occupy, they are, as their name implies, portable. The special requirements of the case demand, therefore, that they be made of small dimensions, and as light as practicable. Economy of fuel, though still an important point, is, in these, subservient to economy in space and weight. A cylindrical tubular boiler is accordingly employed; but the tubes are made of smaller diameter and greater length than those ordinarily adopted, their usual diameter being about two inches, while in length they often run from ten to twelve feet. The number employed, too, is very large; in some powerful engines as many as 300 will be found, and in this way a large heating surface is obtained without unduly increasing the dimensions of the boiler.

There is one difficulty produced by the employment of so many small tubes, the draught is considerably diminished; and as a locomotive engine is obliged to have a very short chimney, no increase can be produced in this way. It is necessary, therefore, to resort to some other means of producing a draught sufficiently powerful to maintain the necessary heat in the furnace, and the way in which this is usually accomplished is by placing at the base of the chimney a steam-pipe, the blast from which quickens the draught to the required extent.

This pipe should be fitted with a funnel-shaped mouth-piece, as in this way a much larger body of air is thrown into motion by it. There is usually a small pipe fitted to this, so that when the engine is at rest, or getting up steam, a small stream may be allowed to escape. When the engine is in action, the waste steam from the cylinders, which escapes at a considerable pressure, is commonly employed, and this it is which produces the series of puffs which may so frequently be observed issuing from the funnel of a locomotive. The draught produced in this manner is so strong that sometimes small pieces of ash or cinder are drawn from the furnace and thrown out of the funnel. These are, of course, very dangerous, and in dry weather crops have thus been set on fire; a screen is therefore employed to intercept them, and let them fall down to the foot of the chimney.

In American locomotives the top of the funnel is usually considerably enlarged, and fitted with a contrivance known as a "spark-trap" or "spark-arrester." This is more necessary there on account of the prairies, which in a dry season are very easily fired, and also because wood is often burnt, and this throws off more sparks than coal does. The details of this trap will easily be understood by reference to Fig. 6. The two inverted curves, *h h*, placed above the central funnel *g*, arrest the sparks, and throw them down into the chambers, *i i*, where they remain, while the smoke and hot air escape through the shaded apertures.

Coke alone ought to be burnt in locomotive boilers, so as to prevent the smoke which is often produced in considerable quantity; but this regulation is by no means rigidly adhered to, and often dense volumes of smoke may be seen issuing from the funnel. The furnace-bars are usually placed so as to slope considerably, and by carefully introducing the coal in front it becomes coked, the smoke given off being mixed with the air and partially burnt in the further part of the furnace; but even with this precaution a good deal of smoke is often given off when coal is employed.

Locomotives for use in countries where wood is plentiful and cheaper than coal, are made with special furnaces for burning wood. The main difference consists in the necessity for an increased area of heating surface, as the heat produced is less than where coal is employed. In an ordinary locomotive about five square feet of heating surface per nominal horse-power is the usual allowance.

The following details of a locomotive passenger engine, exhibited by Messrs. R. Stephenson and Co. at the Paris Exhibition in 1867, will give a general idea of the dimensions of ordinary passenger locomotives. Goods engines are, of course, made much heavier and more powerful, speed being in them of much less importance than tractive force.

The diameter of the cylinders was 16 inches, and the length of stroke 22 inches. The heating surface of the firebox was 83 square feet, and in addition to this there were 161 tubes, 2 inches in external diameter and 11 feet 4 inches long, presenting in the aggregate a heating surface of 960 square feet. The boiler was 4 feet in diameter, and might be safely worked up to 190 pounds pressure per square inch, being made of ½-inch boiler plate. The driving-wheels were 6½ feet in diameter, and sustained nearly one-half the weight of the engine, which was about 30 tons.

There are many general features common to nearly all forms of boilers, to which we must now turn our attention, for at present we have mainly been concerned with the shape and arrangement of the various parts. Copper has occasionally been employed as the material of which they are constructed, and in many respects it is the best material, as it is less liable to become incrusted with the deposit from the water, and is also more durable than iron. The greatly increased expense, however, precludes its adoption, and boilers are almost universally constructed of wrought-iron plates. The best plate-iron should be chosen for this purpose, and it should be very tough, so as to withstand the pressure. The plates are cut so as to overlap one another to a slight extent, and, after being bent to the proper curvature, are firmly riveted together in the manner shown in Fig. 7. The holes should be very carefully punched or drilled, so as to be just the same distance apart in the two plates; if this is carelessly done, so that the holes do not exactly correspond, and the plates have to be forced together by "drifts," and then riveted, the strength of the boiler is much impaired. When the plates are brought together they are temporarily secured, and then a rivet is inserted in each of the holes. The rivets, which should be of the best Lowmoor iron, are first heated in a furnace till they are quite soft; they are then inserted, and immediately hammered down so as to form a good and solid head. As it cools and contracts the rivet draws the plates closer together, and thus forms a tight joint without any packing being introduced. The rivets should be placed at distances of about two inches from centre to centre.

When the boiler is completed, the joints are carefully caulked —that is, the inner edge is forced into closer contact by means of a hammer and cold chisel or punch, and before being used it should be tested by forcing cold water into it till the pressure exceeds that to which it will ever be subjected when at work. Any leak will thus be easily detected. Rings of well-made angle iron are placed round the ends, and also at intervals along the length. Internal stays or struts are also introduced wherever they are considered necessary, to guard against the boiler bulging or collapsing. The different plates should be so arranged that the seams do not form a continuous line either round or along the boiler, each being intermediate to those in the adjoining plates. The reason of this is that the plates become somewhat weakened by the rivet-holes, and the boiler might under pressure part at the seams.

The thickness of the plate-iron employed depends upon the pressure at which the boiler is to be worked, and also upon its diameter. The following is a rule which will give the minimum thickness of plate that ought to be employed, and it is, of course, better to be on the safe side, and exceed rather than fall short of this:—

Multiply the internal diameter of the boiler expressed in inches by the maximum pressure in pounds per square inch of surface, and divide the product by 8,900; the result will give the thickness of the plate in inches.

An example will render this more clear. Suppose we have a boiler whose diameter is 4 feet, and it is required to work it to a pressure of 70 pounds, what thickness should the plate be? Multiplying 48 by 70 we get the product 3,360, which, divided by 8,900, gives us ·377 as the thickness required.

The usual thickness of the plate employed is about three-eighths of an inch, and the rivets have a mean diameter of about five-eighths of an inch, though they vary more or less from this. The plates to which the tubes are fastened in tubular boilers are made considerably thicker, as the number of holes drilled in them materially lessens their strength. For the same reason, whenever an opening is cut in the boiler to admit the steam-pipe or any other fitting, it is well to rivet an internal block round the opening, so as to compensate for the diminished strength. As a result of many experiments, it is found that the tenacity of boiler-plate increases with the temperature up to about 500° or 600° Fahr., but beyond this it diminishes.

In every boiler it is necessary to provide some opening sufficiently large to enable a man or boy to get inside, in case of any repairs being necessary. This opening is known as the "manhole," and must be so arranged that it can at pleasure be closed so as to be perfectly steam-tight. The plan for a long time adopted was to cut an oval hole in the boiler, and procure a plate about an inch or two larger on each side. This could be inserted sideways through the opening, and the edge being smeared with red lead or some similar substance, it was held in its place by means of a screw fixed to it, which passed through a hole cut in a movable arch, placed outside the boiler over the opening. By screwing the nut on the screw, the plate was drawn tightly against the boiler; and the pressure of the steam being exerted outwards, aided in keeping it firm in its position.

This plan has, however, gone almost out of use, and manholes are now constructed on the plan shown in Fig. 8. A circular or oval aperture is cut in a convenient portion of the upper surface of the boiler, and a short tube with a flange at the lower end, so made as exactly to fit the curvature of the boiler, is fitted on over the opening. This tube is securely fastened to the boiler by means of screw-bolts and nuts; packing is also introduced to render the joint tight. On the upper end of the tube is another flange, made quite true, so that a thick plate of iron may be firmly bolted to it, and close the opening steam-tight. Copper wire is sometimes employed in this case as a packing, a ring of it being laid on the surface of the flange, and as the screws are tightened the wire becomes flattened, so as to give a very perfect joint, and one not likely to become injured by the heat.

In addition to this opening, another is required to enable the boiler to be emptied when necessary. The water used often contains a large amount of various mineral salts in solution, and as these cannot pass away with the steam, the water in the boiler becomes so saturated that it deposits a portion as a crust on the internal surface. It is therefore advisable occasionally to let a considerable portion of the water in the boiler escape, and this may be effected by opening this blow-off cock, as it is termed. (Fig. 9). At a convenient portion of the under-side of the boiler an opening is made through the plate, and one end of a large pipe is inserted in this, the other end being closed by a valve able to withstand the pressure of the steam. This valve has a square spindle, and is usually situated just in front of the boiler, or in the ashpit, so that it may easily be got at when required, without being in the way under ordinary circumstances.

Were the boiler left quite unprotected externally, a very large amount of heat would be lost by radiation from its surface, and the building in which it was placed would soon become extremely hot. To guard against these inconveniences, the boiler should be surrounded by some material which is a bad conductor of heat, and which will therefore prevent its escape. For this purpose sawdust is found to answer very well indeed,

In many cases, therefore, the boiler is surrounded with a casing or "lagging" of wood stuffed with sawdust, and when this is done the boiler-room will be quite cool.

The steam-pipes and the cylinder of the engine are frequently jacketed in a similar way. Patent felt and various fibrous substances are in some cases employed in place of sawdust, and answer the same end. In locomotive boilers some protection of this kind is very necessary, since they are so much exposed to the air and weather that the loss of heat would be very large and serious. An incidental advantage of casing the boilers is that when protected they may be touched with impunity, and thus many burns are avoided.

If we examine any boiler we shall find several appendages affixed to various parts: these we must now describe. When a boiler is started it is filled with water up to a certain fixed level, and it is very important that this level should be maintained almost uniform.

The flues are so arranged that no portion of the boiler-plate or tubes shall be exposed to the direct action of the heated air, unless it is protected by being covered inside with water. Some of this water, as soon as the temperature rises, becomes converted into steam, and thus keeps the plate from becoming unduly heated. If now the level of the water falls too low, a portion of the surface will be exposed, and may not improbably be injured by being overheated, and thus rendered so soft as to bulge. Many explosions have arisen from this cause, and the need of great care will therefore be easily seen. As the engine is at work, a portion of the water is converted into steam, and thus the level inside the boiler is continually falling: we want, therefore, some easy mode of indicating at all times the exact level, and also of introducing fresh supplies of water to take the place of that evaporated.

The simplest mode of indicating this is by means of a "water gauge," which is shown fixed on the end of the boiler at B (Fig. 10). This consists of a thick glass tube communicating above and below with the boiler, so that the level of the water in the glass is the same as that of the water inside the boiler. The gauge is usually provided with cocks, as shown in Fig. 11; by means of those at A and B it may be quite cut off from connection with the boiler, so that in case of the glass becoming accidentally broken, the steam and water can at once be prevented from escaping, and a fresh glass can easily be introduced. An additional cock is placed at C, by which the water in the tube can be allowed to escape from it. The tube is usually fixed into its sockets, D, D, by a screw-ring, an india-rubber packing being introduced to render the joint steam-tight.

Another plan frequently employed for ascertaining the level of the water is to place two cocks, A, A (Fig. 10), in the end of the boiler, the one being an inch or two above the other, and the level of these is so arranged that the one shall be a little below the normal level of the water, and the other about as much above it. When, therefore, the water is at the proper height, steam should issue from the upper one when it is opened, and water from the lower one. Should it at any time fall too low, steam will issue from both, and the engineer should then immediately set the feed-pump in action, so as to introduce a fresh supply of water. If, on the other hand, water issues from both cocks, it shows at once that there is too much water, whereby steam space is curtailed, and the proper action of the boiler is somewhat interfered with.

As a general rule it is found best to have as much steam space in the boiler as is equivalent to about eight times the contents of the cylinders; in a small boiler it is well, however, to allow rather more. One disadvantage of curtailing the steam space is that the steam carries with it a larger amount of water in a fine state of division, and this is deposited in the cylinder. To guard against this as much as possible a steam dome (C, Fig. 10) should be provided, and the steam-pipe should start from its highest point.

The door by which fuel is introduced into the furnace of the engine shown in Fig. 10 is at D, while the ashpit is immediately below it. The cock at E shows the appliance by which the quantity of water in the boiler can be reduced at pleasure, or by which the boiler may be emptied when necessary. This cock, and the manner in which it is affixed to the boiler, is shown on a larger scale in Fig. 9.

The description of the arrangements usually employed for injecting water into the boiler we must defer to our next lesson.

ELECTRICAL ENGINEERING.—VI.

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PRIMARY BATTERIES.

The introduction of incandescent lamps for the purpose of domestic lighting during the past few years has created a distinct demand for some convenient kind of electric generator for supplying the necessary current. Friction and influence machines give what might be called currents in the form of sparks, which are intermittent, only lasting for an instant, and which are consequently useless for this purpose. Dynamo machines are in every respect admirably adapted for running incandescent lamps, but they can only be used in large buildings, or where a large supply of light is wanted in a small district. A dynamo needs an engine to drive it, and it would be absurd of any man who required, say, twenty lamps in his house, to go to the expense of laying down the plant necessary to supply those lamps with current, when he could get the same amount of light at a fraction of the cost from gas or lamps. No: the dynamo, though suitable for lighting a number of houses from a central station, does not meet the demand for an electric generator adapted to isolated installations of incandescent lamps. Primary batteries have been specially constructed for giving the required currents, but their want of success has in each case been due to the same cause—the batteries worked well, but they were very expensive. They consumed very little zinc, the liquids used were inexpensive, they gave off no noxious fumes, they required hardly any attention, while the by-products were almost as valuable as the original materials used; in fact, if the inventors were to be believed, "electricity for nothing" was an accomplished fact, and yet none of them have come into general use.

It is as absurd to talk of getting electricity for nothing as it is to talk of getting heat or steam-power for nothing. Electricity is a form of energy, and, in order to produce it, at least as much energy must be expended in one form or other. In the dynamo machine mechanical energy is transformed into electrical energy; in the furnace, potential energy in the coal is transformed by chemical combination with the air into energy in the form of heat; in the battery, potential energy in the zinc is transformed by chemical combination with the liquid into electrical energy in the form of current. The two latter reactions are identical, though the subsequent forms which the energy takes are different. *The battery is neither more nor less than a little furnace*, in which some substance (usually zinc) is burnt up by uniting with the liquid (usually sulphuric acid), just as coal is burnt up by uniting with the oxygen of the air; electricity is produced in one case, heat in the other. That zinc is a fuel, and a good one, may be seen by taking a strip of zinc-foil and lighting the end, when it will burn with a bright blue flame, giving out at the same time more heat than its equivalent of coal. It will not burn in a fire, simply because it melts and runs through the grate before reaching the temperature at which it takes fire.

Zinc, like other substances, has a definite heat-value, *i.e.*, it gives out a definite amount of heat in uniting with oxygen. The following list contains the heat-values of different substances, that is to say, the number of gramme-degrees given out in uniting with oxygen by a quantity of the substance electro-chemically equivalent to one gramme of hydrogen. (A gramme-degree is the amount of heat required to raise one gramme of water 1° Centigrade.)

Substance.	*Heat-*	*Substance.*	*Value.*
Potassium	69,800	Platinum	7,500
Sodium	67,800	Carbon	2,000
Zinc	42,700	Oxygen	0
Iron	34,120	Nitric Acid	− 6,000
Hydrogen	34,000	Black Oxide of Manganese	− 6,500
Lead	25,100		
Copper	18,760	Peroxide of Lead	−12,150
Silver	9,000	Ozone	−14,800

A glance at this list shows us at once the bodies which would give out most heat if burnt in a furnace, or which would give out most electricity if burnt in a voltaic cell. Potassium and sodium stand at the top of the list, but neither of these metals can be used in a cell, as they take fire immediately that they are placed in the oxidising liquid. Their tendency to unite with oxygen is so great that heat is given off sufficiently rapidly to raise the temperature to the point at which the body takes fire. Zinc stands next on the list, and is the metal most used as the fuel in batteries.

If two plates, one of pure zinc and one of copper (Fig. 8), be

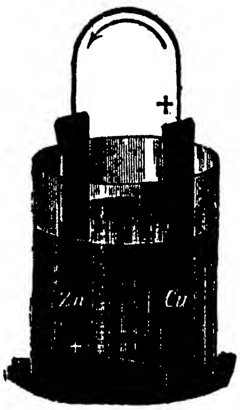


Fig. 8.—VOLTAIC CELL.

immersed in a vessel containing dilute sulphuric acid—care being taken that they do not touch one another, either inside or outside the liquid—no apparent action takes place, neither heat nor electricity is generated. If the plates be now joined outside the liquid by a wire capable of conducting electricity, the former state of things is altered; an electric current is generated at the surface of the zinc, which flows through the liquid to the copper, up the copper plate, through the connecting wire, and so back to the zinc from which it started. The direction of this current is indicated in Fig. 8 by two arrows. At the same time a portion of the zinc unites with the sulphuric acid, and it is this oxidising or burning of the zinc which supplies the energy which takes the form of electricity. The copper plate is not acted upon by the acid, and therefore no electricity is generated at its surface; it plays no part in the action of the cell beyond simply acting as a conductor for collecting the electricity given off from the zinc and conveying it out of the liquid, and so back to the zinc through the conducting wire.

The copper plate in this cell is called the *negative element*, in consequence of the inactive part which it plays in the working of the cell; while the zinc is called the *positive element*, in consequence of its being the metal which acts as the fuel for the supply of the current. In any cell, no matter what its composition, *that substance which acts as the fuel is the positive element*, the other substance is the negative element. The portions of the two plates which project from the liquid are known as the *poles* of the cell; one is called positive, and the other negative. The *positive pole* is the one from which the current starts on leaving the liquid; in the case of the cell which we have been considering, it is the copper plate. The *negative pole* is the one by which the current returns to the cell, and is the zinc plate. The positive and negative poles must not be confused with the positive and negative elements. In the case of every cell *the positive pole is a portion of the negative element, the negative pole is a portion of the positive element.*

While the zinc is being burnt up in the cell, a current flows through the circuit; this current is the equivalent of the energy given out by the burning zinc, and is capable of doing useful work if properly managed; it must, therefore, have been driven through the cell under the action of some force. This force which drives the current through the cell is called the ELECTRO-MOTIVE FORCE of the cell. It is usually denoted by the letters E.M.F.

In order to form a clear conception of what this electro-motive force means, let us take an analogy. If there are two reservoirs, A and B, on the side of a hill, A being situated at a higher level than B, and if we join them by a pipe, what will happen? We all know that the water will flow from A to B. But why does this flow of water take place? Because the pressure due to the force of gravity drives the water from places of high to places of low level, and the rate at which the water flows through the pipe depends upon the difference of level between A and B. Both the water in A and the water in B possess *potential energy*, due to their elevated positions, and the force with which this water will be driven through the pipe depends upon the difference of potential, that is, the difference of height between A and B. The force driving this water we might call gravity-motive force; and in the same sense, in dealing with the voltaic cell, we call the force driving the current the electro-motive force, which in a similar manner depends upon the difference of potential between the zinc and copper plates. The difference of potential of the two plates in a cell really means the difference of their heat-values, or the difference of their tendencies to be burnt up by the sulphuric acid. Both metals tend to unite with the acid; but if a current were to start from the copper, it would be obliged to flow from a place of lower to one of higher potential, analogous to water flowing up a hill—which is impossible. One current only is therefore generated, starting at the zinc; while the zinc itself is

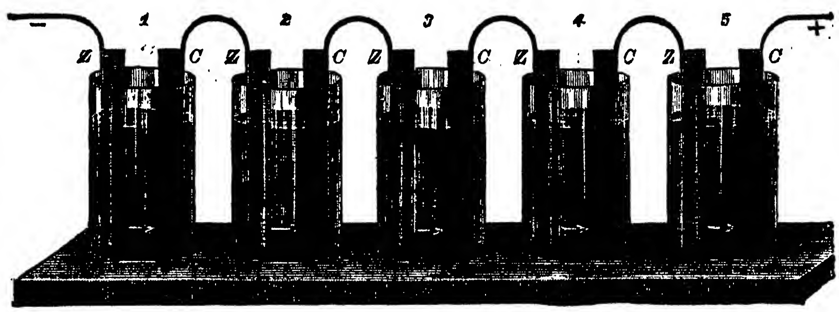


Fig. 9.—VOLTAIC CELLS CONNECTED IN SERIES.

gradually burnt away, giving up its original potential energy in the form of current.

In order to get a greater E.M.F. to drive the current, a number of cells are used, which are connected up as shown in Fig. 9, the zinc of one cell being joined to the copper of the next, and so on. The five cells connected up thus will have an E.M.F. equal to five times that of one cell. Any combination of single cells is called a *battery;* and when they are joined up, as shown in the diagram, they are said to be connected up in *series*.

ANIMAL COMMERCIAL PRODUCTS.—VI.

WOOL (*continued*).

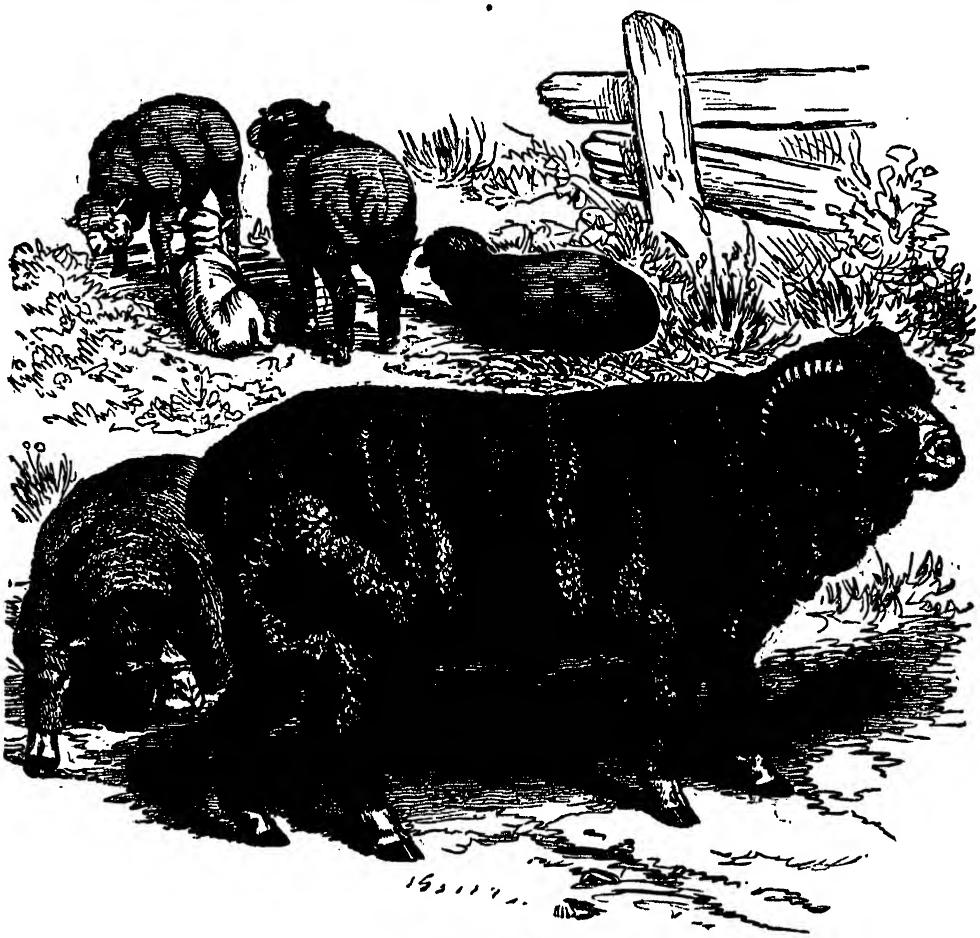
MERINO wool is obtained from the migratory sheep of Spain, a breed which is distinguished from the British by bearing wool on the forehead and cheeks; the horns are large, ponderous, and convoluted laterally; the wool is long, soft, and twisted into silky-looking spiral ringlets, and is very superior in its fineness and felting properties. Its closeness and a luxuriant supply, from the glands of the skin, of yolk or natural oil,

which serves to nourish it and mats the fibres together, render it an excellent natural defence against the extremes of heat and cold. These migratory sheep, amounting in Spain to 10,000,000, are led twice a year (in April and October) a journey of 400 miles, passing the summer in the pastures on the slopes of the Pyrenean mountains, and the winter on the plains towards the south.

The word *merino* signifies an overseer of pasture lands, and is applied to these sheep because in Spain they travel in detachments of 10,000 each, under the care of fifty shepherds and as many dogs, with a mayoral or chief shepherd at their head, and have a general right of pasturage all over the kingdom.

This celebrated breed is now reared in Saxony and in Australia, which has become one of the principal wool-growing countries in the world. In 1464 Spain imported ewes and rams from the Cotswold hills.

The Cretan or Wallachian sheep, remarkable for the enormous development and magnificent formation of its horns, possesses a fleece composed of a soft woolly under-coat, covered with and protected by long drooping hairs. The wool is extremely fine in quality, and is employed in the manufacture of warm cloaks, which are largely used by the peasantry, and which are so thick and warm that they defend the wearer against the bitterest cold to which man can be exposed.



MERINO SHEEP.

" Several of the sheep are tamed and taught to obey the signals of the shepherds; these follow the leading shepherd (for there is no driving), and the rest quietly follow them. The flocks travel through the country at the rate of eighteen to twenty miles a day, but in open country, with good pasturage, more leisurely. Much damage is done to the country over which these immense flocks are passing; the free sheep-walk which the landed proprietors are forced to keep open interferes with enclosure and good husbandry; the commons, also, are so completely eaten down that the sheep of the neighbourhood are for a time half-starved. The sheep know as well as the shepherds when the procession has arrived at the end of its journey. In April their migratory instinct renders them restless, and, if not guided, they set forth unattended to the cooler hills. In spite of the vigilance of the shepherds, great numbers often escape; if not destroyed by the wolves, there is no danger of losing these stragglers, for they are found in their old pasture, quietly awaiting the arrival of their companions."

The chief countries which supply us with sheep and lambs' wool are Russia, Hanse Towns, Argentine Confederation, British Possessions, Africa, British India, and Australia.

There are other ruminant animals from which the wools of commerce are obtained besides the sheep. The following are the chief of these :—

Angora Goat (*Capra angorensis*, Hasselquist).—This animal inhabits the mountains in the vicinity of Angora, in Asia Minor. In colour it is milk white; legs short and black, horns spirally twisted and spreading; the hair on the whole body is disposed in long, pendulous, spiral ringlets, and is highly valued in Turkey, the finest and most costly Turkish robes being manufactured from the fleece, which is as soft and fine as silk. It was first brought into the markets of Europe under the name of mohair. Its exportation, unless in the shape of yarn, was formerly prohibited, but it is now allowed to be exported unspun.

Mohair is transmitted to England principally from Smyrna

and Constantinople. It is manufactured into fine shawls, camlets, velveteens, plushes, braidings, decorative laces, and trimmings for gentlemen's coats. The manufacture is principally carried on at Bradford in Yorkshire and at Norwich in Norfolk, and gives employment to a very considerable number of operatives.

Tibet Goat (*Capra hircus*).—The costly and beautiful Cashmere shawls are made from the delicate downy wool found about the roots of the hair of this animal, which inhabits the high table-lands of Tibet, where these shawls are manufactured These Oriental fabrics are woven by very slow processes, and are therefore very expensive, being sold in Paris at from 4,000 to 10,000 francs a-piece, and in London at from £100 to £400. "The wool is spun by women, and afterwards coloured. A fine shawl, with a pattern all over it, takes nearly a year in making. The persons employed sit on a bench at the frame—sometimes four people at each; but if the shawl is a plain one, only two. The borders are worked with wooden needles, there being a separate needle for each colour, and the rough part of the shawl is uppermost whilst it is in progress of manufacture." To the people of Cashmere this manufacture is very important; about 16,000 looms are continually at work, each one giving employment to three men. The annual sale there is calculated at 30,000 shawls.

It has long been the aim of European nations, on account of the beauty and value of these shawls, to imitate them, if possible, and apply to their manufacture the more speedy and elaborate methods which modern science has placed within our reach. The French have been most successful, and shawls are now produced at Paris, Lyons, and Nismes, known in commerce as French cashmere, which closely approximate in stuff and style of work to the Oriental, whil(much lower in price, although still costly. Norwich, Bristol, Paisley, and Edinburgh have also manufactured very good imitations of these shawls. The Cashmere wool imported for this purpose comes into Europe through Kasan, on the eastern bank of the Volga, and also directly from India and Persia.

The quantity of goats' hair or wool imported in 1886 was 19,527,200 lbs.; the imports of the same material manufactured were of the value of £97,454.

Alpaca (*Llama paco*, Gray).—The llamas may be regarded as the camels of South America, to which tribe of animals they belong. They inhabit the slopes of the Peruvian Andes, and the mountains of Chile, keeping together in herds of from 100 to 200, and never drinking when they have a sufficiency of green herbage. The alpaca is about the size of a full-grown deer, and very graceful in appearance. Its fleece is superior to that of the sheep in length and softness, spins easily, and yields an even, strong, and true thread. Pizarro found this animal used as a beast of burden, and its wool employed for clothing by the natives of that country.

Alpaca wool arrives in this country in small bales, called ballots, weighing about 70 lb., and generally in a very dirty state. It is sorted into eight different varieties, each fitted for a particular class of goods, and then washed and combed by machinery. The principal articles manufactured from it consist of alpaca lustres, fancy alpacas, and alpaca mixtures. Nearly all the alpaca wool imported into England is worked up in the Bradford district.

The *Llama vicuña* and *L. guanaco*, other species of these animals inhabiting the same regions, yield fine hair, but at present of little commercial value.

In 1885 our imports of alpaca (Vicuña and Llama) amounted to 4,556,753 lbs., and in 1886 to 3,926,774 lbs., of the value of £225,168 and £177,012 respectively.

In 1886 we imported 592,544,221 lbs. of wool (sheep and lamb), from Europe, South Africa, the East Indies, Australia, and other countries. Our exports of wool in 1886, to foreign countries and our colonial possessions, amounted to 22,225,200 lbs.

The best wool is grown in Germany, which annually produces 67,200,000 lb. The finest kind passes in commerce under the name of "electoral wool." Next to Germany, Australia ranks in importance as a wool-growing country; the merino breed of sheep has been introduced there with unexampled success. In 1807 the first importation of Australian merino wool was received in England, amounting to only 245 lb. It has now grown to national importance, amounting annually to many millions of pounds in weight. Probably a more extensive and instructive collection of wools was never brought together than that contributed to the Great Exhibition of 1851, in this country; showing, in a remarkable manner, the extent to which wool-bearing ruminants have been fostered by man, their wide geographical diffusion, and the influence of climate in modifying the characters of their fleeces. Samples of wool were there for inspection and comparison, from Chinese Tartary, Tibet, and India in the East, to the lately redeemed tracts of the United States in the far West; and from Iceland and Scandinavia to the Cape of Good Hope and Australia.

Although Europe now surpasses Oriental nations in the artistic working of cotton and silk, yet the same cannot be said of the manufacture of shawls and carpets; for, besides the Cashmere shawls made at Kashmir, in the kingdom of Lahore in Tibet, and also at Delhi in British India, carpets of peculiar and unequalled beauty still come exclusively from Persia and the Levant.

VI.—LEATHER.

Leather is an animal's skin chemically changed by the process called tanning. The skin is prevented from putrefying, and rendered comparatively impervious to water, by the vegetable astringent, tannin, found in the bark, fruit, and leaves of various plants; this uniting with the gelatine of the skin, forms a tannate of gelatine. The skin, thus changed, was called by our Saxon ancestors "lith," "lithe," or "lither"—that is, soft or yielding, whence our term "leather."

The skins are first cleansed from hair and cuticle, by being soaked for several days in a pit of lime water; this loosens the hair and cuticle, so that it is easily scraped off with a curved knife, upon a half cylinder of wood, called a beam. The hair thus removed is sold to plasterers, who use it in their mortar. The skins are now steeped for a few days in a sour liquor of fermented rye or barley, or in weak sulphuric acid. By this process, called "the raising," the pores are distended and rendered more susceptible of the action of the tan. The skins are then put into the tan-pit, in alternate layers, with crushed oak bark, valonia, catechu, dividivi, and other vegetable astringents, and the pit is filled with water. As the tannin is taken up by the skins, it becomes necessary to empty the tan-pit, and add fresh supplies of tanning material and water. The time required to tan the skins, or transform them to leather, depends on their thickness and other circumstances, and varies from four months to two years. When fully tanned, the leather, if cut through, is of a uniform brown colour—anything like a white streak in the centre showing incompleteness in the process. It is now stretched upon a convex piece of wood called a "horse," beaten and smoothed, or passed between cylinders to make it more solid and supple, and lastly, dried by suspension in an airy covered building.

Tanned leather often undergoes the further operation of currying, or impregnation with oil. Leather, prepared as already described, when it is received by the currier is by him rendered smooth, shining, and pliable, so as to make it suitable for the purposes of the shoemaker, coachmaker, saddler, and harness-maker. First, it is soaked in water to render it pliable, then stretched upon the beam and shaved smooth with a knife, next rubbed with a polishing stone, and while still wet besmeared with a mixture of fish-oil and tallow, and hung up in a loft to dry. As it dries, the water only evaporates, the oil penetrating the pores of the leather. The grain, or hair side, is then blackened with copperas water, or sulphate of iron in solution, the iron uniting with the gallic acid of the tan, and producing an inky dye, or a gallate of iron. Leather so prepared is chiefly used for the uppers of ladies' shoes. Leather for the uppers of men's boots and shoes is blackened on the flesh side, or waxed, as it is termed, with lampblack and oil, which is rubbed in with a hard brush. The thick leather for the soles of boots and shoes is simply tanned without being curried.

But leather can be made without tannic acid. Skins may be preserved by means of alum and salt, and leather so made is called in the trade "tawed leather," and is quite as durable and much softer. Gloves are usually made from tawed leather. Skins intended to be tawed pass through a series of preliminary operations, resembling those by which skins are made ready for tanning (the use of ordures is, however, indispensable). They are then immersed in a solution of alum and salt, to which, for the superior kinds of leather, flour and yolk of eggs are added. They are next dried in a loft, smoothed with a warm iron, and

then softened on a stake, when they are dyed of various colours for gloves and ladies' boots. The French are skilled in this art. At Annonay, a town about fifty miles from Lyons, tawing operations are carried on so largely, that 4,000,000 kid-skins are dressed there annually. It has been computed that France and England consume 6,000,000 eggs yearly in preparing kid leather. These eggs are kept in lime-water by the leather dresser, to preserve them until they are wanted. The average quantity of leather gloves annually made in the United Kingdom has been estimated at 12,000,000 pairs. In addition to these we import very largely; thus in 1856 we received as many as 16,887,732 pairs. The imports of raw hides, dry and wet, in 1856, were 1,220,897 cwts.

The leathers known in commerce as *chamois* and *buff leather* are prepared much in the same way as tanned and tawed leather, only that oil is substituted for the alum and tannic acid. The skin of the chamois is not always used; more frequently sheep and doe skin. Wash leather is an example of this kind of preparation.

Russia leather, the smell of which is so agreeable, is prepared in the usual way, then tanned with the bark of the willows (*Salix cinerea* and *Salix caprœa*), and afterwards curried with the empyreumatic oil from the bark of the birch tree, which imparts to it its peculiar odour. M. Chevreul, who investigated the chemical nature of this odoriferous substance, called it *betuline*.

Morocco leather of the finer qualities is made from goat-skins tanned with sumach, and inferior morocco, or roan, from sheep-skins. The hair, wool, and grease are removed as usual, and the skin, thoroughly cleansed, is reduced to the state of simple membrane, called pelt. Each skin is then sewn by its edges into the form of a bag, the grain, or hair side, being outwards. A strong solution of sumach having been put into the bag, it is distended with air like a blown bladder, and the aperture tied up. About fifty of those skins, so distended, are thrown into a tub containing a warm solution of sumach—the tanning liquor—in which they are allowed to float. In a few hours they are tanned, removed from the bath, the sewing is then undone, and they are scraped and hung up in the drying loft. Red morocco leather derives its colour from cochineal, which, boiled in water with a little alum, forms a red liquor, in which the skins are immersed before being put into the sumach bath. In the case of black morocco, the skins are sumached without any previous dyeing, and the black colour is given by applying with a brush, to the grain side, a solution of red acetate of iron; blue is communicated by indigo; puce colour by logwood, with a little alum; green is derived from Saxon blue, followed by a yellow dye made from the chopped roots of the barberry; and for olive, the skins are first immersed in a weak solution of green vitriol, and then in a decoction of barberry root, containing a little Saxon blue.

The thickest and most substantial leather now in general use is that made from the hides of the wild horses found throughout the pampas in South America. It is employed for the soles of boots and shoes, harness, saddlery, leather trunks, hose for fire-engines, pump-valves, military gloves and belts. Deer-skins are used for the finer kinds of morocco leather, and for bookbinding. Calf-skins, tawed, are used by bookbinders; tanned and curried, by boot and shoemakers. Sheep-skins, simply tanned, are employed for inferior bookbinding, for leathering bellows, and other purposes where a cheap leather is required. Morocco leather is used for coach linings, for covering chairs and sofas, bookbinding, pocket-books, etc. A thin leather, called *skiver*, is used for hat linings. There is an immense demand for thin leathers, and machinery for this purpose is now constructed with such accuracy that it will split a sheep-skin into three parts. The grain side of the skin is then used for skiver, the middle for vellum and parchment, and the flesh side is transferred to the glue maker. On parchment we inscribe our deeds, and on vellum all our State documents.

The leather manufacture of Great Britain is of great importance, and ranks next in value and extent to those of cotton, wool, and iron. The census of 1851 showed that 250,000 persons were engaged in the different branches of the leather manufacture, and its entire annual value has been computed at more than £20,000,000 sterling, the leather for boots and shoes alone being valued at £12,000,000. Most of the leather made in the kingdom, and the articles manufactured from it, are used at home. Our exports are, however, considerable, and in 1856 were as follows:—

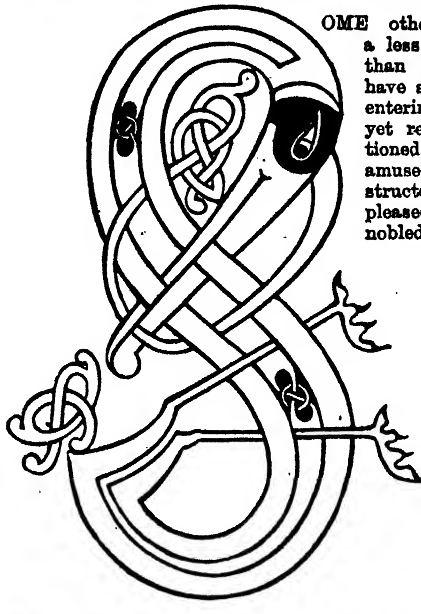
		Value.
Tanned unwrought	152,267 cwt.	£1,302,006.
Boots and shoes	530,357 dozen pairs.	1,546,202.
Saddlery and harness . . .	———	378,094.
Wrought leather of other sorts	———	297,475.

The Australian colonies are the great purchasers of these goods.

PRINCIPLES OF DESIGN.—IV.

By Christopher Dresser, Ph.D., F.L.S, etc.

EMPLOYMENT OF THE GROTESQUE IN ORNAMENT.



OME other principles of a less noble character than those which we have already noticed as entering into ornament yet remain to be mentioned. Man will be amused as well as instructed; he must be pleased as well as ennobled by what he sees. I hold it is a first principle that ornamentation, as a true fine art, can administer to man in all his varying moods, and under all phases of feeling. Decoration, if properly understood, would at once be seen to be a high art in the truest sense of the word, as it can teach, elevate, refine, induce lofty aspirations, and allay sorrows; but we have now to notice it as a fine art, administering to man in his various moods, rather than as the handmaid to religion or morals.

Humour seems to be as much an attribute of our nature as love, and, like it, varies in intensity with different individuals. There are few in whom there is not an amount of humour, and in some this one quality predominates over all others. It not unfrequently happens that men who are great thinkers are also great humorists—great talent and great humour being often combined in the one individual.

The feeling for humour is ministered to in ornament by the grotesque, and the grotesque occurs in the work of almost all ages and all peoples. The ancient Egyptians employed it, so did the Assyrians, the Greeks, and the Romans; but none of these nations used it to the extent of the artists of the Celtic, Byzantine, and the "Gothic" periods. Hideous "evil spirits" occurred on the outside of almost every sacred Christian edifice at one time, and much of the Celtic ornament produced by the early monks consisted of an anastomosis, or network of often grotesque creatures.

The old Irish crosses were enriched with this kind of ornamentation,* and some of these decorative embellishments are of extraordinary interest; but those who have access to the beautiful work of Professor Westwood on Celtic manuscripts will there see this grotesque form of ornament to perfection. As regards the Eastern nations, while nearly all have employed the grotesque as an element of decorative art, the Chinese and Japanese have employed it most largely, and for it they manifest a most decided partiality. The drawings of dragons, celestial lions (always spotted), mythical birds, beasts, fishes, insects,

* Casts of one or two of these can be seen in the central transept of the Crystal Palace at Sydenham.

and other supposed inhabitants of the Elysian plains which these peoples produce, are most interesting and extraordinary.

Without in any way going into a history of the grotesque, let us look at the characteristic forms which it has assumed, and what is necessary to its successful production. We have said that the grotesque in ornament is the analogue of humour in literature. This is the case; but the grotesque may represent the truly horrible or else it may be simply repulsive. This form is so seldom required in ornamentation that I shall not dwell upon it, and when required it should always be associated with power; for if the horrible is feeble it cannot be corrective, but only revolting, like a miserable deformed animal.

Fig. 12.

I think that it may be taken as a principle, that the further the grotesque is removed from an imitation of a natural object the better it is, provided that it be energetic and vigorous—lifelike. Nothing is worse than a feeble joke, unless it be a feeble grotesque. The amusing must appear to be earnest.

In conjunction with this chapter we engrave a series of grotesques, with the view of illustrating my meaning, and I would fain give more, but my space will not permit me to do so.

The initial letter at the commencement of this lesson is a Celtic letter S, formed of a bird. It is quaint and interesting, and is sufficiently unlike a living creature to avoid giving any sense of pain to the beholder, while it is yet in a most unnatural position. It is, in truth, rather an ornament than a copy of a bird, yet it is so suggestive as to call forth the thought of one of the "feathered tribe." It should be noticed, in connection with this figure, that the interstices between certain portions of the creature are filled by a knot. This is well—the whole thing being an ornament, and not a naturalistic representation.

Fig. 11 is a Siamese grotesque head, and a fine sample it is of the curious form of ornament which it represents. Mark, it is in no way a copy of a human head, but is a true ornament, with its parts so arranged as to call up the idea of a face, and nothing more. Notice the volutes forming the chin; the grotesque, yet highly ornamental lines forming the mouth and the upper boundary of the forehead, and the flambeauant ears: the whole thing is worthy of the most careful study.

Fig. 11.

Fig. 12 is a Gothic foliated face; but here we have features which are much too naturalistic. We have, indeed, only a hideous human face with a marginal excrescence of leafage. This is a type to be avoided; it is not droll, nor quaint; but is simply unpleasant to look upon.

Fig. 13 is a fish, with the feeling of the grotesques of the Middle Ages; it is modified from one in Colling's "Art Foliage." It is a good type, being truly ornamental, and yet sufficiently suggestive.

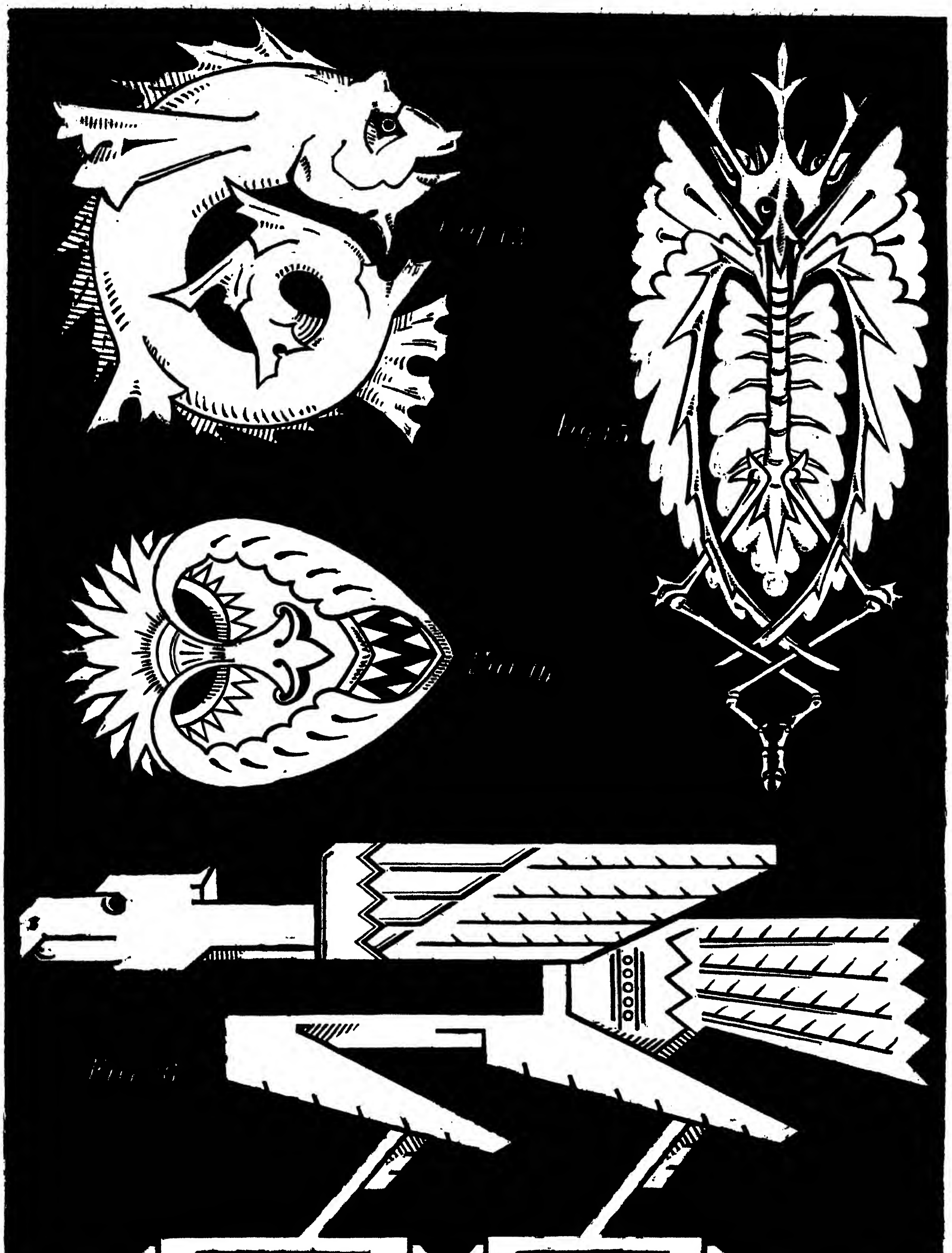
In order that I may convey to the reader a fuller idea of my views respecting the grotesque than I otherwise could, I have sketched one or two original illustrations—Fig. 14 being suggestive of a face, Fig. 15 of a skeleton (old bogey), and Fig. 16 of an impossible animal. They are intentionally far from imitative. If naturalistic some would awaken a sense of pain, as they are contorted into curious positions, whereas that which induces no thought of life or feeling induces no sense of pain.

Of all grotesques with which I am acquainted, the dragons of the Chinese and Japanese are those which represent a combination of power, vigour, energy, and passion most fully. This is to be accounted for by the fact that these peoples are believers in dragons. When the sun or moon is eclipsed they believe that the luminous orb has been swallowed by some fierce monster which they give form to in the dragon, and upon the occurrence of such a phenomenon they come with cans and kettles to make rough music, and thus cause the monster to disgorge the luminary, the brilliancy of which it would otherwise have for ever extinguished. I can imagine a believer in dragons drawing these monsters with the power and spirit that the Chinese and Japanese do; but I can scarcely fancy that a disbeliever could do so—a man's very nature must be saturated with a belief in their existence and mischievous power, in order that he may embody in his delineation such expressions of the assumed character of this imaginary creature as do the Chinese and Japanese.*

Although I am not now considering the structure of objects, I may say that the grotesque should frequently be used where we meet with naturalistic imitations. We not unfrequently see a figure, naturally imitated, placed as a support to a superincumbent weight—a female figure as an architectural pillar bearing the weight of the entablature above, men crouched into the most painful positions supporting the bowl of some colossal fountain. Naturalistic figures in such positions are simply revolting, however perfect as works of sculpture. If weight has to be supported by that which has a resemblance to a living creature of any kind, the semblance should only be suggested; and the more unreal and woodeny (if I may make such a word) the support, if possessing the quaintness and humour of a true grotesque, the better.

It is not the business of the ornamentist to produce that which shall induce the feeling of continued pain, unless there is some exceptional reason for his so doing, and such a reason is of rare occurrence.

* Many fine specimens of Japanese and Chinese grotesques have been exhibited in London from time to time, and some are generally to be seen in the warehouses of importers of such goods.



WEAPONS OF WAR.—III.

BY AN OFFICER OF THE ROYAL ARTILLERY.

GUNPOWDER.

The powder used for the charges of small arms necessarily influences in a great degree the efficiency of the weapons. There is no direction in which English artillerymen have laboured so determinedly, and, on the whole, successfully, as in the direction of the improvement of the powder for guns and small arms. For the moment we are engaged with small arms only; but it will, perhaps, be convenient if we deal with the subject of powder as a whole, and take this occasion to speak generally of the different descriptions of gunpowder in use in the British service.

Gunpowder, as all the world knows, is an intimate mixture of saltpetre, sulphur, and charcoal.

The proportions of the ingredients differ in various countries. The following table, extracted from Captain Goodenough's "Notes on Gunpowder, Prepared for the Use of the Gentlemen Cadets," shows the rates, or per-centage, of the several ingredients in the powder of different countries:—

	Saltpetre.	Sulphur.	Charcoal.
England (Government powder)	75	10	15
France			
Prussia	75	12·5	12·5
United States			
Russia . .	73·78	12·63	13·59
Austria .	76	12·5	11·5
Spain . .	76·47	12·75	10·78
Sweden .	75	16	
China . .	76	14·4	
Switzerland .	76	14	10

English powder has long held almost undisputed supremacy as to excellence of quality and strength. The purity of the ingredients employed, and the elaborate care which is bestowed upon all the processes of manufacture, result in the production of an explosive and propellent agent of great power. Indeed, the chief objection to the English powder has been that it is too strong. We believe that we may safely affirm that there is no powder in the world equal to that which is produced at the Government mills at Waltham Abbey, unless it be the powder which is turned out from the mills of some of the leading English makers, such as Curtis and Harvey, Hall and Sons, and others.

The action of gunpowder is due to the almost instantaneous decomposition of the saltpetre by the charcoal, the latter being burned by the oxygen of the saltpetre, with which it combines in the act of burning to form carbonic acid gas. At the same time the oxygen in the saltpetre becomes separated from the nitrogen with which it was combined.

The explosive force of gunpowder is mainly due to the sudden evolution at a high temperature of these two gases—carbonic acid and nitrogen. In this action, it will be observed, the sulphur plays apparently no part. Indeed, it is a fact that gunpowder may be made without sulphur at all; but the explosive force of a mixture of saltpetre and charcoal is comparatively feeble, because the evolution of the gases in such a mixture is very slow, and the temperature of the gases, and the consequent expansion, relatively small. Sulphur, therefore, which ignites at a much lower temperature than either of the other two ingredients, is added to render the action more rapid, and, by raising the temperature of the gases, to increase their expansive power. Sulphur also increases the volume of the gas, by combining with the potassium in the saltpetre, and so liberating the oxygen with which that potassium was combined, the liberated oxygen becoming available for the burning of the charcoal.

It is to the presence of the sulphur that we owe the white smoke and the solid residue of fired gunpowder. The smoke and residue are chiefly sulphate of potassa (K_2SO_4) and carbonate of potassa (K_2CO_3), resulting from the combination of the sulphur with the potassium. Some of the sulphide of potassium is carried out by the escaping gases, when it catches fire and burns—forming flash and smoke; that portion of it which is not carried out being left in the form of a solid residue.

The explosion of a charge of gunpowder can be effected by raising a single grain of the powder to a temperature of about 600°, which is about the temperature at which the sulphur sublimes. When one grain is ignited, the resulting gases are transmitted by their own expansive power through the interstices, igniting other grains, and finally consuming the whole charge. From this it follows that the ignition of a charge of gunpowder is not necessarily—indeed, it is not under any circumstances—really instantaneous. Gunpowder, in fact, burns, but the combustion generally takes place at so great a rate that it practically amounts to instantaneous ignition. This consideration brings us to a very important branch of our subject.

Those who have followed us thus far will have recognised that the explosive force of gunpowder is not determined alone by the amount of gas developed. It depends upon three main causes: the amount of gas developed; the heat evolved, by which the expansion of the gases is influenced; and the rapidity with which the gases are produced. As to the first two points, we have said all that is necessary for the purposes of the present paper. As to the third point, it is clear that if the rapidity of the inflammation of the charge depend, *cæteris paribus*, upon the rapidity with which each grain successively becomes ignited and consumed, it is possible largely to influence the action of the powder by altering the size and shape of the grains.

Thus, for example, to put an extreme case:—If the powder were not disposed in grains at all, but existed in the form of a solid mass, like what is technically known as "press cake," the inflammation of the mass would be very slow indeed; the flame applied to one portion would flash over the whole surface, and then proceed to consume the mass from outside to within, burning it slowly away in successive layers. If the mass, however, be broken up into an infinite number of small particles, the effect is to open a large number of passages through which the gases at once rush, thus practically igniting each grain in the same instant of time; and in proportion as the individual grains are of a size and shape which permit of their being readily consumed, so will the burning of the whole mass of powder, and consequently its conversion into gases, be rapidly effected.

Here we have the two extremes—of slow and rapid ignition; extremes which are susceptible of modification at will, and between which lie the various applications which the artillerist makes use of. In short, it comes to this, that the action of gunpowder can be largely influenced by mechanical means, and without prejudice to its chemical character. Of course, the chemical character can be influenced by a change in the proportion of the ingredients, in their purity, in their mode of manufacture, etc.; but obviously the better course is first to discover, by theory and practice, the best chemical constitution for gunpowder—that constitution which is capable of producing the maximum results from the three ingredients of which gunpowder is composed—and then to seek mechanically to control the violence or rapidity of the action. In practice, this is what we do in England, and the field of experimental inquiry thus opened out is exceedingly wide.

One interesting application of this theory is that which was proposed by Mr. Gale, the well-known experimentist, of Plymouth. Mr. Gale, following—although perhaps unconsciously—the steps of the French artillerist, Piobert, and those of the Russian chemist, Fadéieff, filled up the interstices of gunpowder with an inexplosive substance, such as finely-powdered glass, and in this way, by cutting off communication between one grain and another, made the powder absolutely inexplosive. Mr. Gale proposed to dilute all powder in store with the ground-glass, and when required for use to sift out the glass, when the powder would resume its natural explosiveness. The idea was ingenious, but it was open to many practical objections, which, in spite of the success that, on the whole, attended the long series of costly experiments which were made, ultimately determined the rejection of the proposition, although at first sight it had appeared to be feasible enough.

More useful advantage is taken of the fact that the explosive violence of gunpowder can be readily controlled by mechanical means, in connection with the adoption, for the different natures of fire-arms, of the powder most suited to them. The size of the charge, the nature of the work required to be done, and the reduction of the strain upon the weapon, are the three considerations which mainly influence the determination of the most suitable

powder. A few words upon each of these points in succession may be useful.

1. *The size of the charge.*—It might be hastily assumed that the size of the charge could not have much influence upon the nature of the combustion, and therefore could not affect the selection of the powder for particular arms. The popular notion would probably be—that if a powder, of a particular size and form of grain and density, burn quicker than another powder in *any* fire-arm, it must burn quicker in *all* arms. And this argument would probably go forward to the conclusion that fine-grain powder must, under all circumstances, burn quicker than large grain. Both these opinions would be erroneous. The rapidity of action of gunpowder depends upon (*a*) the rate of burning of each grain, called the "velocity of combustion;" and (*b*) the rate at which the grains successively become ignited, called the "velocity of ignition." In the case of an open train of powder, the velocity of ignition is independent of the interstices between the grains—the flash travels over and along the train, not through it. So also with small enclosed charges. When the distance which the flame has to traverse is inconsiderable, the velocity of ignition is an element of subordinate importance to the velocity of combustion. In the case of very large charges, however, it is otherwise: the velocity of ignition then becomes a more important element. Consequently, according to the size of the charge, those elements which favour velocity of ignition will have a varying importance, and thus it is impossible to predicate from the size and shape of the grain—which are the elements that mainly influence the velocity of ignition—whether a certain powder will be quick or slow. Other conditions being the same, a fine-grain powder will generally burn quicker than a large-grain, except in very large charges, where a very fine-grain powder will not burn so quickly as the same powder disposed in larger pieces.

2. *The nature of the work to be done* bears, of course, directly upon the selection of powder. Thus, in a smooth-bore musket the chief point is rapidity of action; while, with rifled small arms, regularity of combustion and uniformity of action are of greater importance. Indeed, a very quick powder is unsuited for rifled small arms. In the case of an expanding bullet, such as is used in the Enfield rifle, and which was described in our last paper, it is desirable to make the pressure upon the plug as little of a blow as possible; hence a comparatively slow action is preferred. And in the case of arms firing non-expanding bullets, such as the Martini-Henry—which will presently be described—too rapid a powder, by escaping over the bullet, tends to cause fouling. Therefore, we find that the powder which was used for the old smooth-bore arms, and which was known as "fine-grain," was of a size to be retained upon a sieve of 36 meshes to the inch, and to pass through one of 16 meshes. The powder used for the Enfield rifle is of a size to be retained upon a sieve of 20 meshes to the inch, and to pass through one of 12 meshes. The powder for the Enfield rifle is, however, different from the old smooth-bore powder in other respects than size of grain. It is made with dogwood instead of alder charcoal, the ingredients are more thoroughly incorporated, the density is rather less, and the grains are more rounded, more uniform in form, and more highly glazed. Again, as an example of the adaptation of powder to the work to be done, may be instanced the use of an exceedingly quick powder for the bursting charges of Shrapnel shell, where the powder is required to effect the rupture of the shell and the release of the bullets as instantaneously as possible, so as to diminish the possibility of the charge acting upon the balls. Finally, in the case of all rifled guns, it is necessary to select as uniform a powder as possible, and for rifled guns a special powder has generally been employed.

3. *The reduction of the strain upon the weapon.*—When we have to deal with large guns, we are met by the third consideration which we have named, viz., the importance of reducing the strain upon the gun as much as possible. In the use of small arms this consideration may practically be ignored. The strength of the barrel should be largely in excess of what is requisite to resist the explosion of the regulated charge of gunpowder, however rapid in its action; and the same holds good with regard to field-guns and guns of moderate calibre. But it is far different when we pass from weapons which fire only 70 or 80 grains of powder, or guns which fire only a few pounds, to weapons which consume 40, 60, and 100 pounds of powder at each discharge. The great 35-ton guns built at Woolwich fire 110 pounds of powder—that is, about a barrel and a quarter each. With such charges as these it is necessary to modify the action as much as possible; it is desirable at the same time to do this without diminishing the power of the gun by any reduction in the strength of the powder. This is a problem which has each year become of increasing importance, as the guns and charges have become larger and the strain more severe. It is a problem which accordingly has actively occupied the attention of artillerists for the last few years. The strain which the gun suffers from most is the violent initial strain at the moment of the first ignition of the charge. If the development of gas be intensely sudden, we have a violent local effect, an expression of irresistible force upon the sides and end of the bore before the shot is moved. A familiar experiment illustrates this. If a charge of powder be placed in a thin glass tube, and a charge of fulminating mercury—which, compared with gunpowder, is intensely sudden and violent in its action—be placed in another; and if the two tubes be closed with a cork, and their respective charges exploded, the cork will be blown out of the tube which contains the gunpowder, while the tube which contains the fulminate will be shattered to pieces. What we require in a gun is, not to burst it, but to blow out the shot. It is desirable, therefore, with very heavy charges to modify the action of the powder, and this without altering its chemical character and strength. Accordingly, the size and shape of the grains, their density, and the degree of glazing imparted to them—physical conditions which all affect the rate of explosion—are modified in such a way as to make the explosion less rapid, and to distribute the pressure more evenly through the bore.

With this view the Russians, Prussians, and others employ what is called "prismatic powder"—powder which is compressed into hexagonal prisms, perforated to allow of the passage of the gases. This powder is, no doubt, a great improvement upon the granulated powders; but in England it has been found inferior to both "pellet" and "pebble" powders. "Pellet" powder was adopted provisionally in 1866 for use in very heavy charges. It consists of cylindrical pellets instead of grains—the diameter of the pellets being three-fourths of an inch, and their thickness about half an inch. This was followed by a pebble powder (designated P.), the grains of which were rough $\frac{3}{8}$-inch cubes, to be used with 7-inch rifled muzzle-loading guns and upwards. But even this was too violent; and a larger pebble powder (P_2), with cubical grains of $1\frac{1}{2}$-inch side, was substituted for 12·5-inch guns, and higher calibres. Experiments were made with prismatic powders of about $2 \times 2\frac{1}{2}$ inches grain, or $1 \times 1\frac{1}{2}$ inch grain, each having a hole through the centre; and, finally, a cylindrical pattern (C^2) with grains of $2 \times 1\frac{1}{4}$ inches, also pierced longitudinally, has been found to give, with careful manufacture, more uniform results. Not merely does the use of these large-grained powders greatly decrease the local strain upon the breech end of the gun, being far more gradual in ignition; but it is capable of imparting, with a reduced strain, a far higher velocity to the projectile. Thus, not only is the power of our guns greatly increased, but their time of service is prolonged in proportion to the less strain imposed upon them. The uniformity of action of this powder is also greater than that of the ordinary old-fashioned cannon powder.

The maximum pressure exerted upon an 8-inch gun with 35 pounds of P. powder is estimated at 15·4 tons per inch as against 29·8 tons exerted by the former cannon powder ("Rifle Large Grain"); and the initial velocity of the projectile was increased from 1,363 to 1,410 feet per second. The P_2 powder in the 38-ton muzzle-loading gun was calculated to give a velocity of 1,540 feet per second with a pressure of 22 tons; but the new cylindrical powder gives even better results, for in the 9-inch breech-loading gun it gave a muzzle velocity of 2,075 feet with a pressure of 15·5 tons only.

It appears, then, that while the chemical constitution of all English powder is the same, the physical characteristics of different powders differ widely, the size of grain ranging from the fine "pistol" powder, of which the grains are retained upon a sieve of 72 meshes to the inch and pass through one of 44, up to the pebble powders, which are retained between larger meshes, and the symmetrically formed cylinders of the new pattern grain.

TECHNICAL DRAWING.—X.

DRAWING FOR CARPENTERS: ROOFS.

The whole subject of roofs being very fully treated of in the lessons on "Building Construction," it will not be necessary in this course to give many specimens of them.

The following examples are illustrations of roofs in which iron is combined with wood, by which means far greater lightness is attained than when wood only is employed. In Fig. 70 A A and B B are tension-rods; by screwing up the nuts at the ends of these, the straining-pieces, D D, are forced upward, and being perpendicular to the principals, they give support to them at their middle points. When these tension-rods are tightened, it will be seen that the tie-rod, C, is also strained, and perfect stiffness is thus attained.

Fig. 71 shows the manner in which the principals meet. The apex is covered by an iron plate; this is bent downward so as to form a base for the support of the ridge-timber; a plate extends below the shoe for the attachment of the tension-rods.

Fig. 76 is a similar subject, with an extra breadth of plate, and a third hole into which the end of a vertical tension-rod, which acts as a king-post, is bolted.

Fig. 77 shows the cast-iron shoe for the reception of the lower ends of the principals.

Fig. 78 is a truss used in a railway-shed in Paris, designed by M. Armand. This is an application of Fmys' system of building up the arch-beam of plates of timber, and to this is added a wrought-iron tie-rod, by which the ends are confined; this is tightened up by the tension-rod, A B, in the middle.

Figs. 79 and 80 are the elevation and plan of the junction at B, showing the means by which the tie-rod is tightened up.

Fig. 81 shows another arrangement for attaching and tightening a tension-rod.

In drawing these examples, the student cannot do better than follow the construction as described, and draw the various

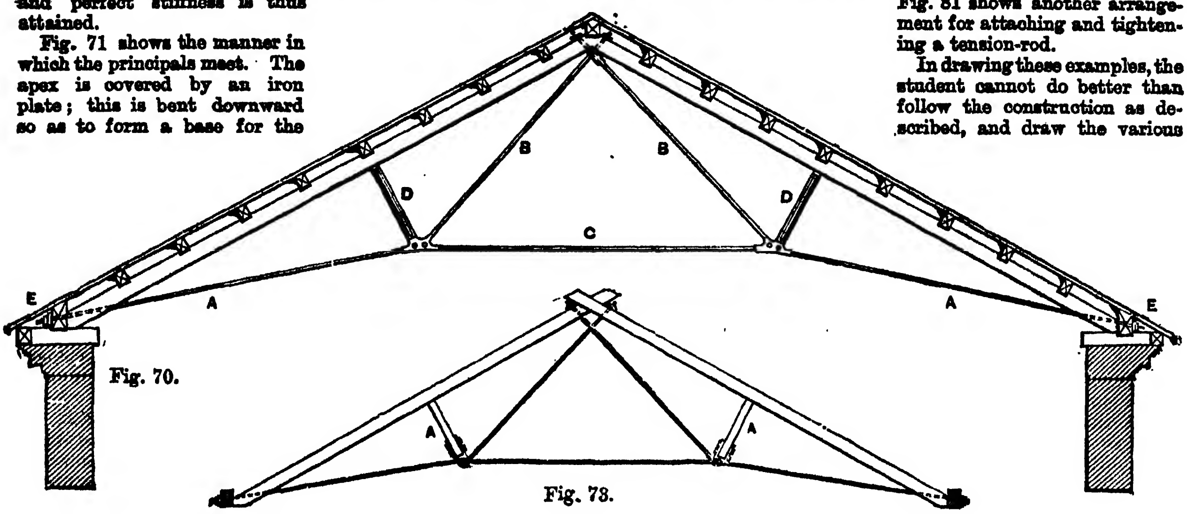


Fig. 70.

Fig. 73.

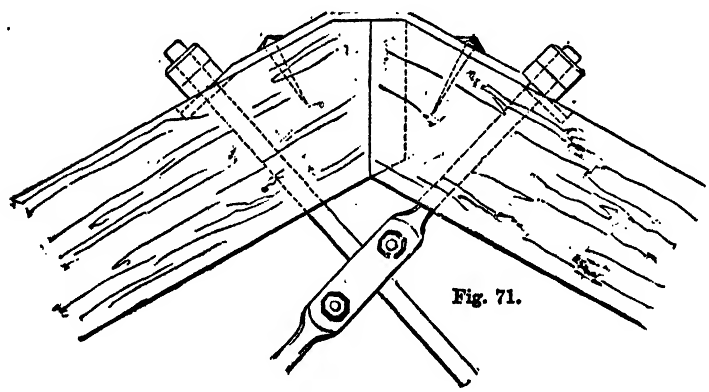


Fig. 71.

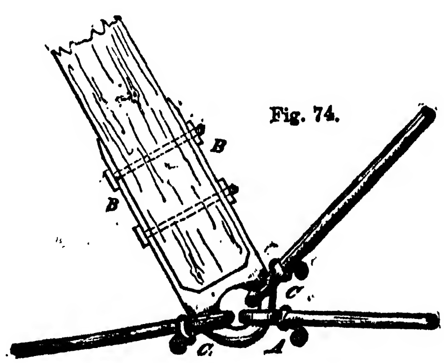


Fig. 74.

nuts, which shall be at right angles to the tension-rods. The nuts are double in order to cause them to act upon a greater length of the rod than would be the case if single ones were employed.

Fig. 72 illustrates the manner in which the nuts act at the lower ends of the principals, a cast-iron boss being attached to the wood-work, with one face slanting, so that in this case also the faces of the nuts may be at right angles to the tension-rods.

Fig. 73 is a roof-truss on precisely the same principle as the other, the difference being merely that the straining-pieces, A A, are of wood instead of cast iron; at their lower end, however, they are fitted with a wrought-iron shoe (Fig. 74, B B), into the ringed end of which the tension-rods hook. These hooks are confined by rings, and their ends are then bent round as shown at C C and A.

Fig. 75 is a section of a cast-iron double shoe, or housing, for the reception of the upper ends of the principals, and also for members in the order in which they would be employed in the construction. He will, by this mode of proceeding, learn to *make* a drawing in an intelligent manner, instead of merely *copying* the lines. It is advisable that the drawing should be made of at least twice the size of the original, and if neatly inked and nicely coloured it will become an important addition to the portfolio. This affords an opportunity of advising each student to provide himself with a portfolio, and to keep his drawings *flat*. When drawings are rolled one over another, they are put away in a drawer or cupboard (if indeed they are so taken care of); those which were drawn first are buried in the depths of the roll, are seldom seen, and are often entirely forgotten; even if taken out for reference, they will not keep flat, but are wrinkled and difficult to measure from. On the other hand, if the drawings are neatly cut off the board, and kept in a portfolio, they are constantly kept before the eye, and the student is thus reminded of subjects and of principles,

which would otherwise have formed only a single study, possibly never to be looked at again. Portfolios may now be had at a very low price, and the student is assured that the amount will be very well laid out.

Having drawn the sections of the walls in Fig. 70, draw a horizontal line across from top to top, and projecting beyond the walls as far as the eaves at E E are intended to overhang the walls of the building.

failure, each fault will become worse and worse as the work proceeds, and the incorrectness will be so evident that he will have to give up the work in an incomplete state, thus wasting all the time and trouble that have been bestowed upon it.

If, however, the student, in making a drawing from any of the examples that have been brought under his notice, should find that either from inattention to some preliminary point of detail or miscalculation of the scale, he is going so far wrong

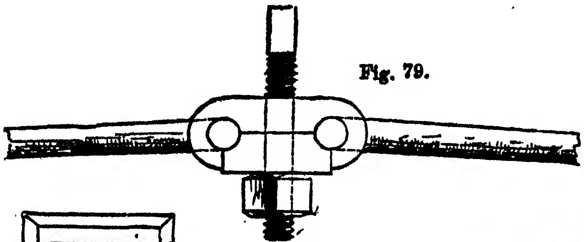


Fig. 79.

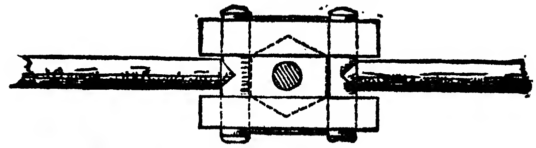


Fig. 80.

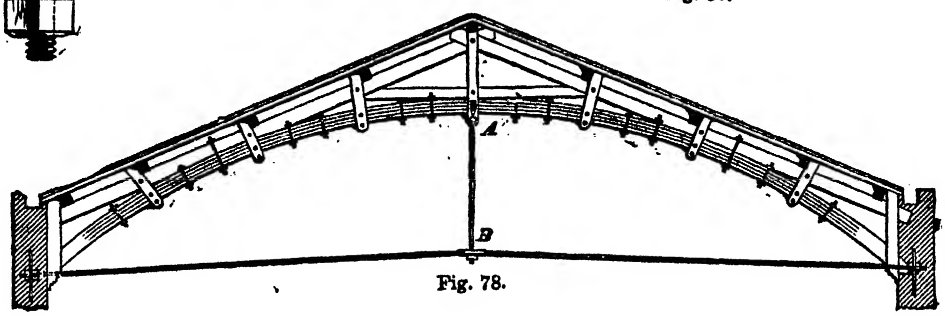


Fig. 78.

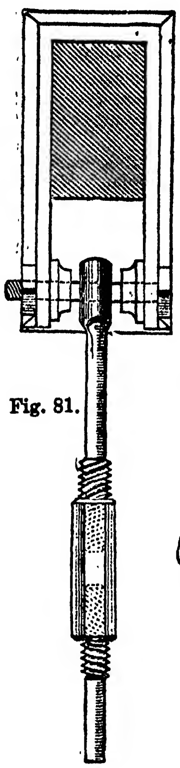
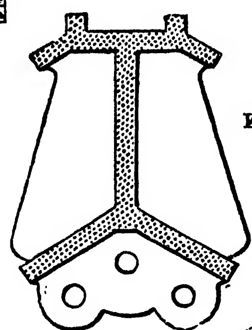


Fig. 81.



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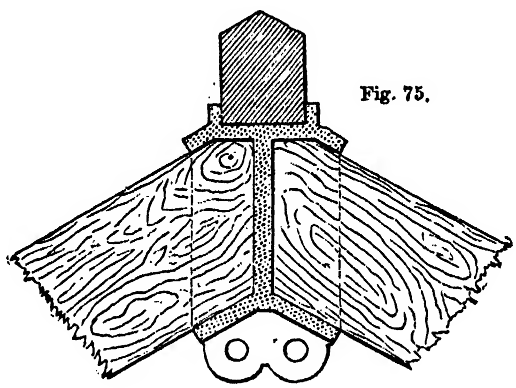


Fig. 75.

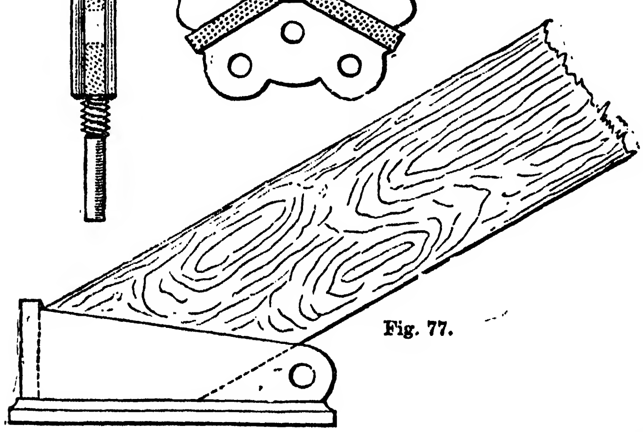


Fig. 77.

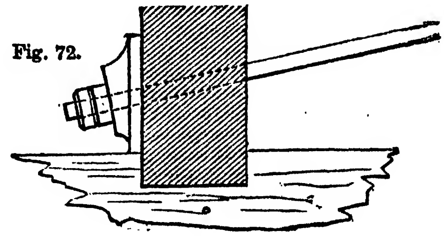


Fig. 72.

At the middle point of this horizontal erect a perpendicular, and mark on this the height of the angle where the rafters meet.

Next draw the rafters, the straining-pieces, D D, and the tension-rods, A A, B B, and the tie-rod C; then follow the purlins, and the rest of the roof, as shown in the example. The construction at the apex has been shown in Fig. 71, and this is to be followed in the complete drawing. The nuts at the ends of the rafters, too, are to be copied from Fig. 72.

The student is again urged to aim at absolute accuracy and refinement in his work, and is warned that unless he is very careful in the elementary operations the drawing will be a

that he is obliged to give up the piece of work that he is engaged on, he should not be discouraged, but renew the attempt on fresh paper until he has succeeded to his satisfaction. Perseverance, he must remember, never fails to bring its reward.

In drawing the ends of the purlins, for instance, the greatest care must be taken that they are all one size, and that the spaces between them are equal. This will be best accomplished by using two pairs of dividers, the one to be kept to the width of the purlins, and the other for the spaces. This will avoid the inaccuracy caused by frequently changing the size held in the instrument, and will be by far the more rapid plan.

VEGETABLE COMMERCIAL PRODUCTS.—V.

V. PLANTS USEFUL IN THE PREPARATION OF NUTRITIOUS AND STIMULATING BEVERAGES.

THE TEA-PLANT (*Thea viridis*, L., and *Thea bohea*, L.; natural order, *Camelliaceæ*).—These two species are probably only varieties of the same plant. Native region, China and Japan.

The tea-plant is an evergreen shrub which attains in a state of nature a height of from twenty-five to thirty feet, but under cultivation seldom exceeds five or six feet in height, owing to the removal of its foliage by the cultivator. The leaves are alternate, short-petioled, smooth, shining, ovate-oblong, stiff and coriaceous, and slightly dentate.

All the numerous varieties of tea known in commerce are referable to one or other of the two grand divisions of green and black tea. Both are most undoubtedly produced by the same plant, the difference in their colour resulting simply from a difference in their mode of preparation.

The green teas comprise Twankay, so called after the name of a stream in Che-kiang, where this sort is produced; Hyson, or, in Chinese, *yu-tsien*, meaning "before the rains," in allusion to the time of gathering; Gunpowder, or *ma-chu*, "hemp-pearl," referring to the peculiar globular form into which the leaves are twisted; Imperial—the finest kind of green tea—so named because it is only used by the emperor and the mandarins: this tea consists of the smallest and most tender light-green leaves of the first gathering; it is not easily obtained in Europe in the pure state.

The black teas include Bohea, named with reference to the range of the Bu-i hills, where it is grown; Congou, or *koong-foo*, signifying labour or assiduity; Souchong, or *siau-chung*, meaning small or scarce sort; and Pekoe, or *pe-kow*, "white hairs," in allusion to the down on the epidermis of the young spring leaves. The two last are the finest and most expensive of the black teas.

The preparation of green tea may be described in general terms as follows:—The leaves are gathered from the shrub, and placed in bamboo baskets; they are then put into shallow iron pans, placed over charcoal fires, and stirred continually and briskly, the rising steam being fanned away; after this, they are removed from the pans, and whilst still flaccid with the contained moisture, are placed before the twisters, on a table made of split bamboo, and therefore presenting ridges; the twisters roll them over with their hands until twisted. The leaves are then spread out and exposed to the action of the air, and afterwards returned to the drying-pans, exposed there to additional heat, and kept continually stirred until the drying is complete, when they are picked, sifted, sorted, and so prepared for packing. Black tea is prepared in the same manner, with this difference, that the fresh leaves, as soon as collected, are thrown together into heaps, and allowed to lie until a slight degree of fermentation ensues, or a spontaneous heating, similar to that which takes place in a damp hay-stack. This partial fermentation of the tea-leaves darkens their colour. All the black teas are grown in Fokien, a hilly and populous district about 200 miles to the north-east of Canton. The green teas are raised in the district of Kianguan, about 750 miles from the same city.

Owing to certain peculiarities in Chinese legislation, landed property is much subdivided, so that the tea is generally cultivated in small gardens or plantations, the leaves being picked by the family of the cultivator. The first gathering takes place in early spring, in the month of April: pekoe and hyson are made from this crop. It is scarcely over before the air becomes charged with moisture, rain falls, and this, combined with the warmth of the atmosphere, causes the tea-shrubs soon to put forth, in the month of May, the leaves of the second crop. A third gathering is made about the middle of June, and a fourth in August. The leaves of the first gathering are the most valuable, and from these the finest imperial and hyson, with pekoe and similar qualities of black teas, are prepared. The leaves of the last crop are large and old, and consequently make preparations very inferior in flavour and value.

During the harvest season, when the weather is dry, the Chinese may be seen in little family groups on every hillside, engaged in gathering the tea-leaves. They strip off the leaves with astonishing rapidity, and throw them into small round baskets made for the purpose out of split bamboo or rattan. These baskets, when filled, are emptied into larger ones, and immediately conveyed to market, where a class of Chinese make it a business to collect them in large quantities, and partly manufacture them, drying them under a shed.

A second class, known as the tea-merchants, purchase the tea in this half-prepared state, and complete the manufacture, employing in the operation women and children. The tea-merchants begin to arrive in Canton about the middle of October, and the busy season continues until the beginning of March, being at the height in November, December, and January. The tea is brought to Canton either by land-carriage or by inland navigation. The roads are too bad to admit of beasts of burden attached to wheeled vehicles, so that the land-carriage is usually effected by porters.

In China tea is the common beverage of the people, being sold in the public-houses in every town, and along the public roads, like beer in England. It is quite common for travellers on foot to lay down their load, refresh themselves with a cup of warm tea, and then proceed on their journey. A Chinaman never drinks cold water, which he abhors and considers unholy; tea is his favourite drink from morning to night, not mixed with milk or sugar, but the essence of the herb itself, drawn out with pure water. The Chinese empire could hardly exist were it deprived of the tea-plant, so habituated are the people to its use; and there is no doubt that it adds greatly to their health and comfort as a nation.

The Japanese usually make tea by pouring boiling water on the leaves, after having first reduced them to powder. Neither the Chinese nor the Japanese use milk or sugar with tea; and certainly the peculiar taste and aroma of the tea are better appreciated without these additions.

Tea is imported in chests always lined with thin sheet-lead, and with a paper which the Chinese manufacture from the liber or inner bark of the paper mulberry (*Broussonetia papyrifera*, L.). It is silky in texture, straw-coloured, and made without size. When the tea is put into the boxes, it is pressed down first with the hand, and then with the feet, after which the boxes are nailed down and stamped with the name of the district-grower or manufacturer.

The Chinese colour with Prussian blue the teas which they ship for the foreign market. Only a little of this dye is employed, so that its use is not productive of evil results; still, the tea would be better without it. The Chinese never dye the teas which they retain for their own use. The green teas of commerce are too often only black teas coloured with Prussian blue. Nevertheless, comparatively speaking, very little adulteration of tea is practised by the Chinese. A few leaves of the *Camellia* and of a species of *Rhamnus* or buckthorn indigenous to China are found occasionally amongst the tea-leaves, but not to any very great extent. The leaves of such British plants as the beech, elm, willow, poplar, hawthorn, and sloe, are far more abundant, proving that the tea is adulterated after it has arrived in this country. The adulteration is easily detected by comparing the leaves from the teapot with the genuine tea-leaf. Tea is also adulterated with old exhausted tea-leaves, which are re-dried and used again.

In 1866, 230,669,292 lbs. of tea were imported into the United Kingdom, of which quantity 178,909,881 lbs. were retained for home consumption; in the same year we exported 44,931,020 lbs. to foreign parts.

The consumption of tea by the Chinese themselves is enormous. They drink four times as much as we do. With rich and poor of all that swarming population, tea—not such as our working classes here drink, but fresh and strong, and with no second watering—accompanies every meal. The population of China, according to an official census taken in 1825, was 352,866,012, which is ten times greater than our present population. Thus the consumption of tea in China must be forty times greater than the consumption in this country. In addition to this there is a very heavy exportation in native vessels from China to all parts of the East where Chinese emigrants are settled, such as Tonquin, Cochin-China, Cambodia, Siam, the Philippines, Borneo, the settlements in the Straits of Malacca, California, and Australia. In comparison with such an enormous amount as this our own consumption sinks into insignificance.

The caravan or Russian teas are the best and most expensive of those used in Europe. They are brought overland from China by Russian merchants, who go there annually in caravans, *viâ*

Kiakhta. These caravan teas, purchased by the wealthier Russian families, are preferred to those shipped in Canton, which are said to deteriorate in some degree through the sea air, and from being stowed away in the narrow and close holds of the vessels.

Tea was first brought to Europe by the Dutch in 1610, and they had for a long time the monopoly of the trade. But the British East India Company, entering the field as a competitor, soon obtained a fair share of the business. The sole object of the company was to provide tea for the English market; of this they had the exclusive monopoly until 1834, when the British Government passed an Act which threw open the tea-trade to all disposed to engage in this important branch of commerce.

Formerly all the tea received in Europe was cultivated exclusively by the Chinese; now the culture of the tea-shrub is successfully carried on in other countries.

The Dutch were the first to break the charm of the Chinese monopoly by introducing and cultivating the tea-plant in the rich and fertile island of Java. Their first experiment was so successful that numerous tea-gardens were soon under cultivation on the mountain range which runs through the centre of the island, where the plant escapes the scorching heat of the torrid zone, and finds a climate by height, rather than by latitude, adapted to its nature. A considerable quantity of tea is now annually shipped from Java to Amsterdam.

In 1810 an attempt was made to cultivate the tea-shrub in the Brazils, near Rio de Janeiro, and a colony of Chinese were induced to settle there, and attend to the plantations. But the experiment did not succeed: the shrubs became diseased, and the Chinese formally abandoned them. Another effort made in the same country in 1817 was unsuccessful, owing to difficulties arising from climate, the high price of labour, and the natural indolence of the natives. The experiment, however, was tried once more, and this time successfully, and tea culture is now prosecuted with energy in the Brazils, and with a commensurate amount of success. The Rio Janeiro market is entirely supplied with tea of domestic growth, and the public of Brazil are satisfied that no plant is more profitable or deserving of attention.

Tea is now cultivated in British India. Some years ago it was discovered that the tea-plant was indigenous to our Indian territory of Upper Assam. This plant, supposed to be a distinct species, has received the name of *Thea assamica*. It is a more vigorous plant than the Chinese species, and has much larger leaves. It grows in the warm, moist valleys of the Himalaya mountains, the temperature and other conditions there being similar to the circumstances under which the Chinese plant is raised. The Assam Tea Company was started, and several thousand acres were soon under cultivation in the district stretching from Kumaon to the *hill tracts* acquired from the Sikhs. The plants grown are chiefly those raised from Chinese seed, the remainder are the indigenous plants of the district. The seeds of the Chinese plant were obtained by Mr. Fortune in China in the summer of 1850, and by him planted in Wardian cases. They germinated during the voyage, and reached their final destination—the plantations of the Himalayas—in fine condition. About 14,000 plants were thus added to the Assam collection. Chinese tea-curers have been induced to settle in Assam, and both black and green tea are now manufactured from the Chinese and Assam plants. The latter produces a very strong tea, which answers well to mix with the low sorts of China tea, and is chiefly used for this purpose. Large cargoes of tea from Assam are continually being received in this country. Land suitable for the culture of tea exists amongst the Himalayas to an almost unlimited extent, and the quantity raised annually and exported must increase as the plantations are extended and multiplied.

OPTICAL INSTRUMENTS.—II.

By Samuel Highley.

THE ABNORMAL EYE.

Having described the characteristics of the perfect and healthy organ of vision, we have now to describe the deviations from the normal eye, and those defects or diseases that require the optician's aid for their correction or alleviation. Between thirty and fifty years of age indications of natural decay in the perfect organ of sight may be detected, and it will be found, as a rule, that while distant objects are as distinctly discernible as in youth, it becomes necessary to hold *near objects*—such as the newspaper, needlework, etc.—further from the eye than the person has hitherto been accustomed to do, especially in candle or gas light—it is, in fact, becoming *long-sighted*. The average distance for distinct vision for near objects in the normal eye is about eight inches from the eye; but on long-sightedness setting in, near objects cannot be distinctly discerned till removed to a distance of fourteen, sixteen, eighteen inches, or further, from it. This defect is termed *presbyopia*. The commencement and progress of this deterioration of the normal eye depends upon how it has been used, and upon the health of the individual. At thirty years of age some eyes are more defective than others are at fifty years, but the average period of the commencement of decay in the eye is about the forty-fifth year, and is first indicated by feeling the necessity of removing small type further from the eye when reading by candle or gas light, and the consequent necessity for using spectacles. This will be about a year before their assistance during daylight is recognised as absolutely essential for the comfort of the organs of vision.

Presbyopia, it may be stated, is often accompanied by that "weakness of sight" termed *amblyopia*; and the latter is sometimes mistaken for the former, as the amblyopic person also cannot see small objects distinctly, and convex spectacles (as with presbyopia) improve his vision by affording larger retinal images; but the purely presbyopic eye is free from amblyopia.

About the age of fifty the far point, in the normal eye, also begins to recede somewhat, so that the eye then becomes slightly hypermetropic (or of the defective nature next described), and with increasing years may become absolute, so that the patient is unable to accommodate not only for divergent rays from near objects, but even for parallel rays from distant objects.

Another shortcoming, which may be present in youth, is where the eye, when in a state of rest, is incapable of bringing the parallel rays emanating from *distant* objects to a distinct focus on the retina, and can only do so by an effort of accommodation more or less considerable, according to the amount of defect, while no great inconvenience may be experienced in regard to near objects, when reading, writing, sewing, etc.—in fact, may never be detected till age sends the person so affected to the optician or oculist, especially if he has good accommodative power, when the defect is unconsciously corrected with but slight effort. If, however, this defect is absolute, vision will not be perfect at any point. This is termed *hypermetropia*, an affection which was little noticed, or not properly understood, until within the last few years. Another deviation from the normal eye (which has no connection with age, but is, as a rule, a natural, often hereditary defect from birth, though seldom discovered by the person so affected till the age of puberty, or till the commencement of earnest study, or occupation at some trade or profession involving the use of the eye at its near point, or in other cases resulting from occupations teasing to the eyes) is *short-sightedness*, or *myopia*, as it is professionally termed. In this case persons can see the very smallest object perfectly when brought unnaturally close to the eye, while large ones at a distance, or even a moderate distance, are involved in such haziness, that they would not be justified in swearing to the recognition of an accused person in a court of justice.

All eyes—the emmetropic,* hypermetropic, and myopic—suffer change in the near point with the advent of old age. The eye is not adjusted at the same time for equally distant *horizontal* and *vertical* objects, being greater for horizontal lines than vertical ones, which may be proved in the following manner:—Draw on paper two ink lines at right angles to each other, and place one horizontal. At the distance of distinct vision, this will appear black and sharp, while the other will be indistinct, as if drawn in paler ink; adjust the eye for the vertical line, and the effect will be reversed. In some cases this difference in the curvature of the eye in two directions may become so great as to require optical correction by means of "cylindrical lenses." This defect is termed *astigmatism*.

Some persons (always affected with slight myopia) complain that after reading for a short time without glasses, the letters become confused, blurred, and appear to run into each other:

* The presbyopic is classed with the emmetropic eye, being in fact a normal eye defective through age and not by congenital malformation.

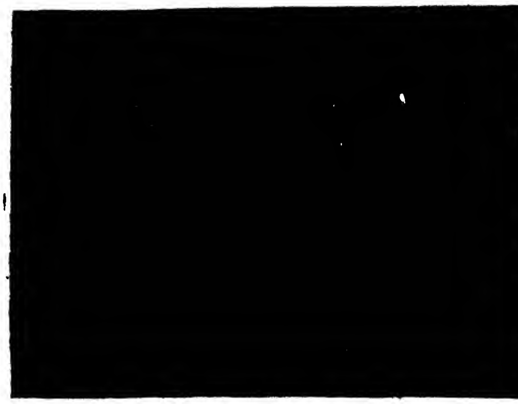
pain in the eye and around the orbit is experienced, and, if persisted in, the eyes become red and watery. After resting the eyes for a few minutes, reading may be proceeded with, but only to entail a speedy return of the same train of symptoms. If we request such a patient to look at our own forefinger, while we gradually approach it towards his eye, we shall find that when it is within a distance of about six inches, one eye becomes a little unsteady in its fixedness, and then gradually, suddenly, or spasmodically deviates outwards. Again, this deviation occurs even, perhaps, if the object be some feet distant, when we cover one eye, so as to exclude it from participating in the act of vision of the other. This outward deviation indicates insufficiency or weakness in the *recti interni* muscles of the eyeball, which tends to the production of double images of the objects observed (or what is professionally termed *diplopia*), which the patient intuitively suppresses, unless the object be brought too near to the eye. If such a person persists in employing the eye on near objects, the affected eye moves outwards and produces a permanent divergent squint (*strabismus*), in which case the patient again suppresses the image of the squinting eye, to avoid the production of diplopia, which leads to more or less of that "weakness of sight" of the affected eye termed *asthenopia*. By the judicious selection and employment of prisms of suitable refractive power, this weakness of the muscles, if attacked in *the early stages*, may be cured, and thus the surgical operation of tenotomy may be avoided. Such prisms must be weak at first, and then be

gradually increased in power. The prism must be placed with the base outwards before the affected eye, so that the rays from a candle, placed about eight inches distant, may fall upon a portion of the retina slightly to the outer side of what is known as the yellow spot (*fovea centralis*). To avoid the production of double images arising from this, the eye will instinctively move inwards, in order to bring the rays exactly upon the yellow spot. During these exercises of the internal rectus, short-sighted eyes must be furnished with concave spectacles, so that the object may be distinctly seen. This mode of treatment requires great patience on the part of oculist and patient.

Oculists classify eyes according to their diopteric characteristics when tested for their *furthest point* of distinct vision, and four kinds may be specified :—

1. The *Normal*, or *Emmetropic Eye*, in which, when in a state of rest, parallel rays are brought to a focus *on* the retina, as shown at *i* (Fig. 2, page 111).

2. The *Presbyopic*, or *Long-sighted Eye* (aged emmetropic), in which, through the loss of accommodative power, caused partly by the weakening of the ciliary muscles, partly by the hardening and discolouration of the crystalline lens,* and the flattening of the cornea, the faculty of bringing *near objects* to a focus on the retina is lost, unless the object be removed to an [illegible], in a state of rest, is capable of bringing *parallel rays* emanating from a distant object to a focus *on* the retina, and so far is a normal eye still, while the converging rays from a near object come to a focus behind the retina, as shown in Fig. 6. This defect is remedied by holding the object at a distance from the eye, so as to lessen the divergence of its rays, or by placing a convex lens

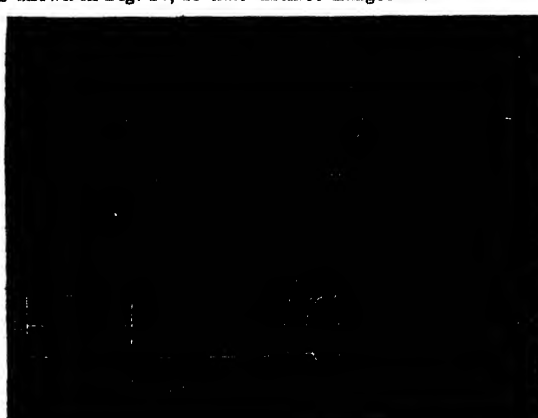


before the eye, so as to help it to produce the necessary convergence, as shown by the dotted lines in Fig. 7.

3. The *Hypermetropic*, or *Over-sighted Eye* (*hyperpresbyopic*, or *hyperopic*), which is adjusted for convergent rays, but in which parallel rays are brought to a focus *behind the retina* when the eye is in a state of rest, as shown in Fig. 8. This results from the length of the axis being too short—in other words, the retina being too near the cornea—or through the refracting surfaces of the eye being slightly flattened, or both causes may be co-existent. In either instance the refracting part of the organ of vision is incapable of converging parallel rays from a distant object, so as to bring them to a focus on the retina. The *hypermetropic* eye may be diagnosed by its peculiar shape, as it appears flatter and shorter than the normal eye, and it does not fill out the aperture of the lid, a little pouch being left between the eyeball and lid.

Hypermetropia is remedied by placing a convex lens before the eye, so as to help it to produce the necessary convergence of the parallel rays, and bring them to a focus on the retina, as shown by the lines (Fig. 9).

4. The *Myopic*, or *Short-sighted Eye* (*brachymetropic*), which, when in a state of rest, is adjusted for divergent rays, and wherein parallel rays are, even when the eye accommodates itself for its farthest point, brought to a focus before the retina, as shown in Fig. 10, so that distinct images are formed on the



retina only when the rays emanating from such object fall upon the eye di ergently

This results from the axis of the eye being too long, or the curvature of the refracting surfaces being too great. This defect is remedied by holding the object very close to the eye, so as to increase the divergence of its rays, or by placing a concave lens before the eye, so as to produce the necessary divergence, as shown by the dotted lines (Fig. 11).

* The crystalline lens is as transparent as water till about the twenty-fifth or thirtieth year, when it begins to be slightly tinged with yellow towards its centre, which very gradually extends towards the surface, and becomes deeper and deeper in tint, till in extreme old age it may resemble a piece of yellow amber.

FORTIFICATION.—III.

BY AN OFFICER OF THE ROYAL ENGINEERS.

PROFILES OF HASTY AND IRREGULAR DEFENCES.

THE destructive effects of rifled arms render it absolutely necessary that cover of some kind should be rapidly provided for the troops acting on the defensive, and it must often happen that a regular profile cannot be given to works only intended for the temporary occupation of a field of battle.

Advantage must then be taken of all such materials existing on the spot (walls, hedges, etc.), as are capable of being readily converted into parapets; and where no such materials exist, cover must be obtained by means of what are called Shelter Trenches (Fig. 15). The object of these is to secure for the defenders, by a small amount of labour, considerable protection whilst firing (as may be

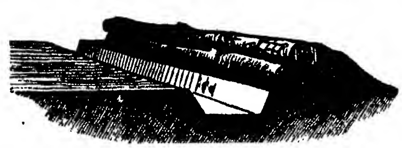


Fig. 18.

accurately with the blades of their shovels, which are about 1 foot in length. Care must be taken that after the parapet has been raised to a height of 1 foot 6 inches, the additional earth is not allowed to increase this height, as it would then be too high to be fired over by men kneeling in the trench. In rear of each company, short trenches will be dug for the officers and non-commissioned officers (Fig. 17), who will then be in their right places for superintending the firing, and only so far back from the line, that when the main trench is completed, their own parapet shall not be interfered with.

As will be seen in the accompanying cuts, the men in these trenches are much less exposed than those in the open, and as they are absolutely out of sight when lying down and not actually engaged, many lives must be saved by the cover they afford; at the same time the proportion of fatal wounds to the total

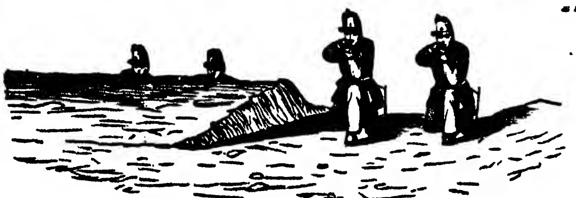


Fig. 15.

SCALE 40′ TO 1 INCH. Fig. 19.

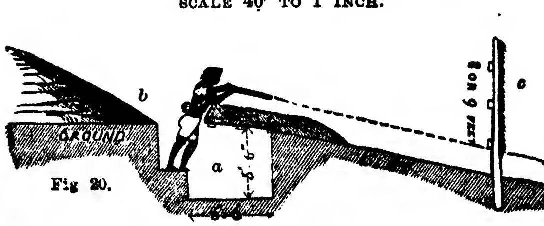
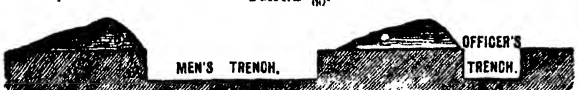


Fig. 20.

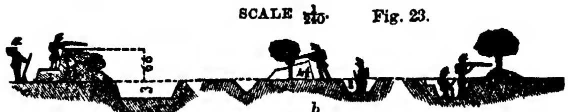
SCALE $\frac{1}{120}$.

Fig. 16.

SCALE $\frac{1}{60}$. Fig. 17.



SCALE $\frac{1}{240}$. Fig. 23.



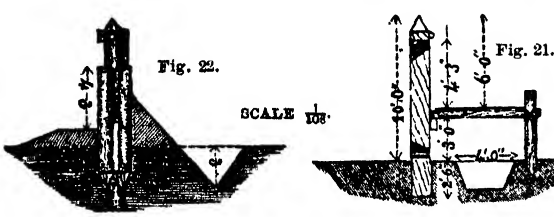


Fig. 22. SCALE $\frac{1}{108}$. Fig. 21.

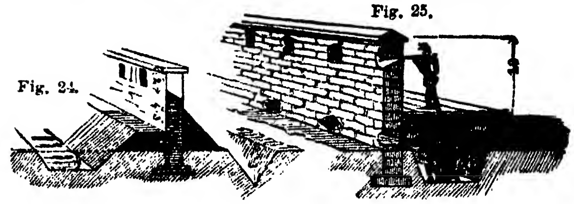


Fig. 24. Fig. 25.

seen by comparing the men shown in the open in the figure and those in the trench); and, at the same time, not to obstruct their rapid advance when the moment for a forward movement arrives. The method of executing them is as follows:—As soon as a regiment arrives on the ground it is intended to defend, one rank is extended as a line of workmen, at six feet intervals from one another. In the first instance, a continuous trench 1 foot 3 inches deep, and 2 feet broad, is dug, the earth being thrown in front to form a parapet 1 foot 3 inches high. This trench can be excavated in from ten to twenty minutes, and is then capable of giving cover to one rank kneeling in it, and to a rear rank lying down on the ground behind (Fig. 16).

If more time is available, the trench is then gradually widened until it is 7 feet broad, when it is wide enough to allow of the men lying down in it, and being perfectly hidden until required to fire (Fig. 17).

As soon as it is 4 feet wide, there is room for both ranks kneeling. No tracing or special measurements are necessary for this work; for if the men are placed in line, two full paces apart, they can measure the depth and breadth sufficiently

number of men hit must be larger than before, since the men's heads are almost the only parts exposed. This was noticed in some of the battles in France during the Franco-German war, where trenches of this description were employed. In woods, where large trees can be easily obtained, parapets may be formed by felling the trees, and, after removing the branches, laying them lengthways one above another, as represented in Fig. 18. If shovels are available, a small trench should be excavated, and the earth thrown over the logs. A very serviceable parapet may thus be readily formed, as the crest, which is usually the weak part of all earthen parapets, is in this case quite bullet-proof.

The entrenchments used by the Maories or New Zealanders are worthy of notice, both on account of their being somewhat different from the ordinary profile, and also because the same method may be advantageously applied in cases where it is desirable to defend a hill-side with several rows of men in shelter trenches, one behind the other. Their pahs, or entrenched positions, were generally admirably chosen on the slopes of hills, inaccessible or difficult of approach, and the

ground most liable to attack thoroughly well swept by their fire. These works generally consisted of an irregular line of deep rifle-pits, as represented in Figs. 19*a*, 20*a*, placed close to one another, connected either by a trench (*b*) or a small underground passage, and the earth being thrown up *behind* the trench instead of in front, as is usually the case. This mound served the double purpose of affording cover to their huts and dwelling-places, and, if necessary, could be manned to bring a second line of fire to bear on the attack. The men in the pits, firing at the level of the ground, were very little exposed, besides which the narrowness of the pits and their irregular outline made it difficult to dislodge the defenders by the fire of shells. The front was usually protected by a stout palisade, or post-and-rail fence, on which a screen of flax was hung (*c*)—the former as an obstacle to prevent the assailants closing with the men in the pits, who were hidden from view by the screen, and were able to fire under it close along the ground. Some of the pits were partially roofed in and lined with fern to serve as sleeping-places, as may be seen from the enlarged section through rifle-pit in Fig. 20. An interesting detailed account of these may be found in Vols. VI. and XIV. of the "Professional Papers of the Royal Engineers."

Stockades are formidable parapets constructed entirely of wood in situations not exposed to artillery fire. They are so high as to necessitate the use of ladders to get over them, and being bullet-proof and loopholed are troublesome to attack, as unless they can be approached by surprise, many casualties must occur in attempting either to escalade them, or to blow them in with gunpowder.

Stockades are the type of work usually met with in wars with uncivilised nations who do not possess artillery, such as the Hill tribes on our Indian frontiers, etc. One of these works in Bhootan proved a very formidable obstacle, formed of long bamboos firmly lashed together, and was not demolished by the explosion of 60 lb. of powder placed in a bag against its foot. Ordinary stockades consist of a row of upright timbers 12 or 14 inches in diameter, and from 10 to 15 feet in length, placed touching one another, with their butt ends buried in a trench 3 or 4 feet deep. These logs are kept together by being spiked to two rails, or cross-pieces, near the top and bottom of the logs on the inside (Fig. 21).

To increase the difficulty of getting over them, their tops should be pointed, and where they come in contact the logs should be squared, by having slabs cut off each side.

If this cannot be done, smaller logs should be placed in front and in rear, to strengthen the weak points between the large timbers.

The larger the logs are the better, both on account of the greater security they afford, and also because they are not so liable to be dangerously weakened by cutting a loophole through them. This is generally managed by cutting a notch equal to half a loophole out of each of two adjacent logs, and placing them together.

As the usual method of demolishing a stockade is by exploding bags of powder placed against them, it is desirable to prevent this as far as possible, by digging a ditch in front, and piling the earth at a steep slope against the stockade on the outside. This should generally be done, unless the lower portion of the stockade requires to be loopholed so as to allow of a second tier of musketry fire, when a temporary platform or "banquette" must be erected inside to enable one row of men to fire over it, while another rank stand in a trench at the first of the timbers, and fire through close to the ground level (Fig. 22).

With regard to loopholes generally, it will be well to remember that they should invariably be made at a level either too high or too low for the enemy to use for firing into the work from the outside; and, at the same time, they must be at a convenient height on the inside for use by the defenders. About 15 feet of ordinary stockade work can be constructed by a party of eight men in eight hours. This does not include cutting down, or bringing the timber to the spot. Strong **hedges** afford excellent defensive obstacles, and are capable of being converted with little trouble into good parapets.

When a hedge is less than 6 feet high, a ditch should be dug, and the earth thrown over to the other side to form a parapet, as the hedge is then utilised as an obstacle, and also as a revetment to the earth behind (Fig. 23*a*). This method gives the men firing over the hedge a command over their assailants.

When time presses, and the hedge is high and strong enough to form a good obstacle, a slight trench with the earth piled against the hedge will suffice to obtain cover. A small ditch (Fig. 23*b*) should be added outside to keep the enemy from closing with the breastwork. In some instances it will be better to make the trench deeper, and having cut away the lower branches, to fire close to the ground (Fig. 23*c*). Hedges intended as obstacles may be very much strengthened, and made difficult to cut down, by having thick iron wire run through them and made fast to the largest trees in the hedge. As it is the exception to find hedges without some sort of bank or ditch on one side of them, the excavations that have been indicated in these diagrams will generally require very slight work to complete, and consequently this species of defence may be very rapidly prepared.

Walls of moderate thickness may be rendered defensible by either breaking loopholes through them at the required levels, or cutting openings down from the top, care being taken that the wall is not too much weakened by this treatment, and that the enemy is prevented from closing with the loopholes from outside.

On level ground, walls under four feet high are useless as parapets, but may be of service as a partial revetment to earthen ones thrown up in front of them (Fig. 24).

Low walls, under 7 feet high, require that a ditch and a trench should be dug in order to obtain sufficient cover. High walls may be arranged for two tiers of musketry fire, in the same way as has been described for a stockade (Fig. 25).

In the hasty defence of villages and towns, rough **barricades** formed of carts, furniture, etc., may be employed both as obstacles and parapets. No rules can be laid down for their construction, except that they should be placed at points where their fire can be assisted from loopholes in adjacent buildings, and where artillery fire cannot be brought to bear on them from a distance. Four-wheeled carts filled with stones, earth, etc., would form a good commencement for a barricade if drawn up in a line across a street, and their hind wheels taken off. Behind these, logs of wood, sacks filled with coals, barrels, etc., would be accumulated until a sufficient parapet and banquette had been formed; a pile of broken wheelbarrows, furniture, etc., being arranged in front as an obstacle, but so as not to afford cover.

TECHNICAL EDUCATION AT HOME AND ABROAD.

IV.—IMPORTANCE OF DRAWING—NEED OF TECHNICAL EDUCATION FOR MANAGERS.

BY SIR PHILIP MAGNUS.

ART INDUSTRIES (*continued*).

In the designing of patterns for textile fabrics, such as fancy flannels, trouserings, damasks, curtains, carpets, etc., and equally for printed goods, whether the material be cotton, linen, or paper, a knowledge of technical art is much needed. Indeed, as mechanical contrivances can only approach to the versatile and varied capabilities of human labour, special technical knowledge is more needed for designing patterns to be executed by machines than for those intended to be worked by hand. Thus, in calico-printing, a trade extensively carried on in Manchester and in Mulhouse, the designer must not only be familiar with the kind of patterns that will suit his material, and that will be adapted to his market, but he must also understand the capabilities of the machinery which will produce those patterns. He is not free to select every hue and colour from the spectrum that may suit his purpose, as the ordinary artist can do, but he must know how to produce the maximum of effect with the minimum of shades, seeing that every additional colour involves additional expense. Even in the process of block printing, by which the best designs are still obtained, this technical knowledge is required; but it is still more necessary in machine-roller printing, the method generally adopted in the manufacture of printed goods.

In this particular branch of trade, English manufacturers still depend very much upon foreign help in the production of designs; but every year the importation of patterns, which are chiefly French, is likely to decrease. In many other industries, notably in lace manufacture, in carpets, in metal-work, the

designs of English artists are chiefly used by English manufacturers, and native designers are engaged by firms which, a few years since, employed foreigners almost exclusively. In Nottingham the designing of the patterns is now almost wholly in the hands of Englishmen; in some of the largest works at Birmingham, English artists are generally employed in the place of foreigners; and not only are English designs used in preference to others for carpets and furniture hangings, but the goods of this description manufactured at Glasgow are largely exported to France, Germany, and other parts of Europe, as well as to the United States. This result is due to the dissemination of art teaching among artisans, mainly through the action of the Science and Art Department at South Kensington. Much, however, remains to be done in the way of making art instruction more general than it is at present, also in making it more subservient to trade purposes, and in specialising the instruction in particular localities, with a view to the necessities of the staple industries of the district. In our review of foreign schools we shall see to what extent this is done abroad, and also what facilities are afforded in these schools for obtaining a practical knowledge of the *technique* of different trades.

Although considerable progress has been made of late years in this country in applying art to trade purposes, we may expect that the progress will be still more marked when drawing is more generally taught in our public elementary schools. Hitherto the teaching of this subject has been neglected. From the published official returns of schools in which drawing is taught, it appears that in the year 1886, out of 19,022 schools in England and Wales, drawing was taught in not more than 4,446; and that out of 2,922,351 children, between the ages of 7 and 13, receiving instruction in these schools, drawing was taught to not more than 870,491. It appears, therefore, that of all the children over 7 years of age who are being educated in the State-aided elementary schools, more than two millions, or about 70 per cent. of the total number, receive no instruction in that subject which, throughout Europe and the United States, is justly regarded as the basis of a sound technical education.

Now, considering that there is no period in life when the hand and eye can be so well trained to work in harmony as during early childhood, greater attention should be given to the teaching of drawing than has been hitherto devoted to it in this country. One advantage of teaching drawing generally to all children is that designers will be more easily selected from among the artisans engaged in that particular trade for which they have to provide designs, and consequently they will be better able to appreciate the requirements of the material to which their designs have to be applied than those who, having been trained as artists and failed as such, subsequently seek employment as trade designers.

TECHNICAL EDUCATION FOR MASTERS AND EMPLOYERS.

Thus far we have spoken of technical education in respect to the requirements of artisans in manufacturing works in the various branches of the building trade and in art industries. We now come to say a few words on the education of masters, principals, and superintendents of works.

Nothing impresses one more strongly, in passing through English and foreign manufacturing works, than the superior technical knowledge of the French or German mill-owner or manufacturing chemist, as compared with his English competitor. This arises from the fact that abroad there are special schools for the training of persons who expect to be occupied with productive industry, in which they receive that kind of education which best fits them for understanding all the duties of the work in which they are to be engaged. In these schools, which in Germany are known as Technical Universities, the young man learns the principles of chemistry, physics, and mechanics; he acquires a sound and practical knowledge of machine construction and drawing; he obtains a considerable familiarity with two foreign languages; he gains a knowledge of industrial geography, of political economy, and of the technology of the trade he intends to follow.

This advanced education, which he continues until he reaches the age of 21 or 22, not only enables him to make the best use of the training he receives in the works themselves when he enters them, but gives him habits of observation and reflection, which direct his attention to the consideration of important matters of detail, upon the due appreciation of which the success of a manufacturing industry often depends. Besides this, he learns to make use of the experience of others, readily to adopt improvements in machinery and in processes of manufacture, and to apply new scientific discoveries to the purposes of his own trade, and, above all, the importance of thoroughly understanding every detail of his work and the conditions of production in his own and in foreign countries.

It is sometimes thought that this education is carried too far in foreign schools, that young men are kept too long from the experiences of actual and real work, which they can obtain only in the engineer's office, in the mechanic's shop, or in the mill. But against this view it must be pointed out that one's entire life is a school of experience, and that one seldom enters it too late to profit by it, whilst theoretical instruction can be obtained in youth alone. What is true of other professions is doubtless true of engineering, architecture, or manufacturing industry. The professional education of the soldier, the lawyer, or the physician is protracted to the age of 21 or 22, and no one doubts the advantage of this thorough training. The education which men intended for these professions have now for some time received has been "technical" in the true sense of the term. It has been practical and theoretical. It has had for its object the training of the man with strict reference to his career. The student of a military college combines theoretical instruction with practice intended to afford him an insight into the actual work he would have to direct in a battle or a siege. So, too, the medical student has to make himself acquainted with the fundamental principles of chemistry, physiology, and zoology, that he may be able to trace to their ultimate causes the phenomena he meets with in actual practice, and in order that he may be able to explain new combinations of circumstances which no mere empirical knowledge could have led him to foresee. In this country, it is only of late years that it has been necessary for the lawyer to receive a truly technical education before commencing to practise. But now-a-days no one thinks of complaining that the period of preliminary study is too long. It is not many years ago, however, that we were told that there was no training school so good as actual experience, and the sooner a man cast aside his books and commenced work the better. But the application of science to military and naval warfare has rendered a thorough technical education absolutely necessary for the training of an efficient officer; and I suppose no one would now suggest that the doctor's apprentice, by mixing drugs and by occasionally assisting his master in his operations, would obtain the same advantages as the medical student can gain by attendance at the science schools and wards of a London hospital.

On the Continent, it has long been recognised that the same kind of education which best fits a man to become a surgeon, physician, or a soldier is applicable to the training of those who are to occupy the higher posts in engineering works or in manufacturing industry. It is quite true that in many cases men rise to the top of their profession who have received, as youths, a very inadequate preliminary education; and it may be equally true that education tends in some cases to impede the development of native genius. But arguments of this kind tell against all kinds of education, and not more so against the technical instruction of the manufacturing chemist than of the physician or military engineer. Abroad, the similarity of the cases is fully acknowledged, and the Polytechnic schools of Germany and Switzerland, and the École Centrale of Paris, are expressly intended to provide this higher education for those who have the time and the means to avail themselves of it.

In England, only recently have efforts been made to add to our colleges or higher schools special departments for the technical instruction of persons who are intended to occupy superior posts in industrial works. To the literary and purely scientific education which these institutions originally afforded have been added schools of practical and applied science, laboratories, drawing offices, and machine shops, and in many places this technical side of our colleges is becoming the more important. In this way, on a small scale, schools corresponding somewhat to the Polytechnic schools of the continent have been gradually growing up in connection with our higher colleges. This gradual growth of a technical side to colleges affiliated to the

Universities is peculiar to this country; and the association of these educational institutions with the older Universities prevents us, at first, from seeing that many provincial colleges are in reality schools similar in character to some of the technical schools of the Continent, with the addition of classical and literary courses. Nothing, perhaps, is more indicative of the change that has taken place in our views of what higher education ought to be than the fact that institutions like the Firth College, Sheffield, and University College, Nottingham, which owed their existence to the system of university extension, should have added to their courses a technical side, which is very likely before long to affect the general character of these institutions. University teaching proper has made of late years less progress in this country than is generally supposed, whereas the extension of technical instruction has been very considerable, and has brought us within measurable distance of foreigners in the opportunities these schools afford for the more advanced technical education.

On the Continent, trade and commerce owe much to the higher education of the captains and superior officers of the various crafts. In industries, the development and success of which depend upon the application of science, the results achieved by foreign manufacturers are much more due to the training of the masters than of the men. In their knowledge of chemistry, the Germans and Swiss are undoubtedly ahead of us, and they have utilised this knowledge in the establishing of important industries abroad, which might equally well have flourished in this country. Of this no more conspicuous example can be quoted than the manufacture of artificial colouring matters. The production of these substances from what were once considered the waste products of gasworks, requires the application of the highest knowledge of organic chemistry; and so successfully has this knowledge been applied to the manufacture of these substances, that, whilst the raw product is generally exported from this country, it is manufactured in Germany and Switzerland, which countries are thus benefited by an important industry.

The knowledge of chemistry, which the Germans especially have shown themselves so well able to apply, has not been acquired exclusively in any technical school. The Polytechnic schools of Germany are well supplied with costly laboratories, replete with every possible convenience. But it is not in these alone that German chemists have been trained. Chemistry has for many years been regarded as a subject of university education. To the general establishment of laboratories Liebig gave the first impulse. In nearly every German university the chemical laboratory occupies as prominent a position as in the Polytechnic schools. In Munich the university laboratory is in every respect superior to that of the Polytechnic in the same city; and in the new University at Strasbourg, a separate building is devoted to the teaching of chemistry.

In the Universities of Germany many of the chemists have been trained who have done so much towards developing chemical industries in that country; and this development is certainly due rather to the higher training of the masters and managers than to the superior education of the men employed in the works. A chemical factory in Germany may be regarded as a laboratory on a very large scale, every part of which is presided over by an efficient chemist; and it is to the supervising care of these sub-managers, and to the frequent improvements they introduce, that the success of the German manufacturers is mainly due.

PROJECTION.—VIII.

SECTIONS OF CONES AND PENETRATIONS OF SOLIDS.

THE PARABOLA.

If a cone be cut by a plane parallel to one of the sides of the triangle which forms its elevation, the section is called a *parabola*.

Fig. 95.—*To draw the parabola which shall be the true shape of the section of the cone* A B C, *on the line* D E, *which is parallel to* C B.

Divide E D into any number of parts, in F G H, and through these points draw lines parallel to the base, meeting the sides of the triangle in *f*, *g*, *h*, *i* on each side. Now it will be evident that all sections of a *right* cone which are parallel to the base must be circles; and therefore, as the base A B of the elevation is represented in the plan by the circle A′ B′, the line *f f* in the elevation will be represented by the circle *f* in the plan; and similarly, the lines *g* and *h* in the elevation become the circles *g* and *h* in the plan.

From E in the elevation draw a perpendicular, which, passing through the plan, will give the line E′ E′. This is the line where the section-plane, entering the cone at D, will cut the base. A perpendicular dropped from D will mark on the diameter the plan of the top of the section—viz., D′.

An additional point, I, has been inserted between H and D, in order to gain more points for tracing the curve. This point is to be worked similarly to the others.

It has been shown that the section-plane cuts the elevations of circles *f g h i* in F G H I, and therefore perpendiculars dropped from these points to cut the plans of these circles, will give the points *f*, *g*, *h*, *i* in the plan. The curve drawn through these points, together with the straight line E′ E′, forms the *plan* of the parabola, being the view of the slanting surface E D as seen from a point of view immediately over the cone.

To draw the true shape of the section, draw a line D″ E″ parallel to D E, and from D, E, F, G, H, I draw lines at right angles to D E, passing through D″ E″ in F′, G′, H′, I′. On each side of these points, mark on the lines drawn through them the distances which the points E′, E′, *f*, *g*, *h* in the plan are from the diameter A B—viz., *f*, *g*, *h*. Through these points draw the curve, which will be the true parabola formed by the plane cutting the cone in the line D E.

THE HYPERBOLA.

Fig. 96.—When a cone is cut by a plane which is parallel to the axis, the section is called the *hyperbola*.

In this case the object of the lesson is to find the true section of the cone, caused by a plane, of which D E is the edge elevation, cutting it parallel to the axis. Rotate the cone on its axis so that the section shall face the spectator, in which position (Fig. 97) it will evidently be parallel to the vertical plane. Now from C in the plan, draw any number of circles, cutting the line *e e* in *f*, *g*, *h*. The diameters of these circles will be marked by the points *f′*, *g′*, *h′*. From these draw perpendiculars cutting the side of the cone; and the lines *f″*, *g″*, *h″* drawn parallel to the base will give their elevations. Now from the points in the plan where the section-line cuts the circles—viz., points *f*, *g*, *h*—draw perpendiculars cutting the lines *f″*, *g″*, *h″* in *f*, *g*, and *h*; then from D (Fig. 96) draw a line to cut the axis in D′, and perpendiculars from *e′ e′* to cut the base of the elevation in *e e*. The curve drawn through all these points will be the required hyperbola.

THE PENETRATION OF SOLIDS.

When one solid meets another it is said to *penetrate* it, and the development of the form generated at the intersection of the bodies is a study of the utmost importance to artisans. The lessons we are now giving on this subject commence with those of the most elementary character, and advance by very gradual stages. Only fundamental principles are, however, developed, in order to prepare the student for the advanced studies which will be given in subsequent lessons adapted to the respective branches of industry.

Fig. 98 represents the plan and elevation of a square prism penetrated by another of smaller size, their axes* being at right angles to each other, and two of their faces being parallel. The figure at this stage is so simple that it requires but little explanation. The points not visible in the present view, owing to their lying exactly beyond others, are marked with letters corresponding to those on the points which are in front of them, with the addition of a dash (′), and the points themselves will become visible in Fig. 99, where the object is rotated.

Fig. 99.—Place the plan at any angle (as required). The projection will then be accomplished, as in previous figures, by drawing perpendiculars from the points in the plan, and intersecting them by horizontals from the corresponding points in the elevation. Points G and H will mark the line of penetration—that is, the line at which the smaller prism enters the larger.

Fig. 100 is the development. The widths of the sides being equal to A B, and the length to the height of larger prism, the squares represent the cavities through which the smaller

* *Axes*, plural of *axis*.

prism would pass if the development were folded into a square form.

Fig. 101 represents the plan and elevation of a square prism penetrated by a smaller one, when the axis of the latter is at an angle to that of the former. The student who has followed the lessons to this point will find no difficulty in projecting the plan from the elevation, and by turning the plan, to project the view given in Fig. 102. The object, however, of the lesson is to show that, although the penetrating prism is *square*, the opening through which it is to pass, and which it is to *fill* up, is an *oblong*. The reason of this is, that although the width of the prism from E to F is not altered by being placed obliquely, the line A B across the side C D is longer than E F. Therefore, having developed the surface of the larger prism (Fig. 103), draw horizontals from A and B, which will give the top and bottom of the oblong, which is to be made of the width E F. The aperture on the opposite side is to be projected in the same manner from G H.

Fig. 104 shows the development of one of the ends of the smaller prism. Full directions for working this figure have already been given in Fig. 34.

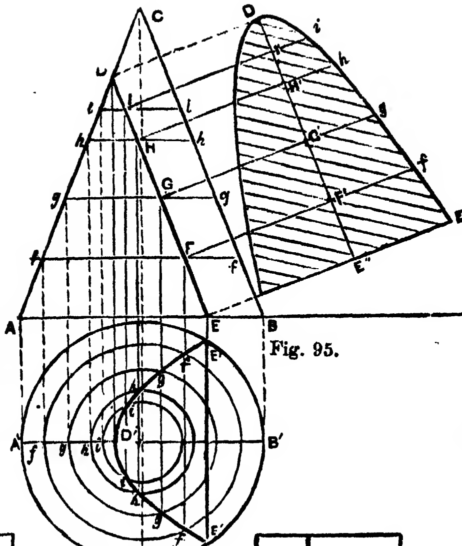


Fig. 95.

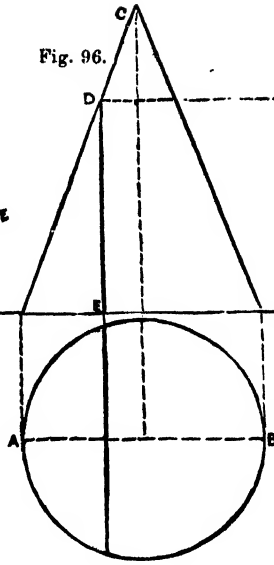


Fig. 96.

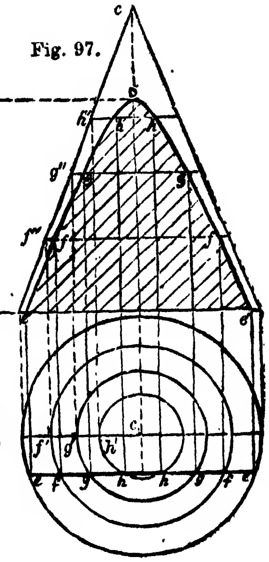


Fig. 97.

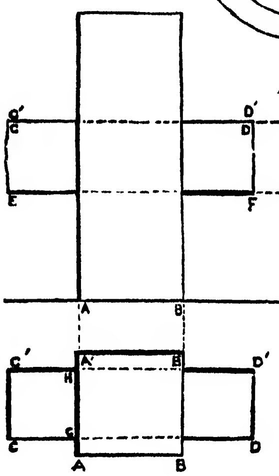


Fig. 98.

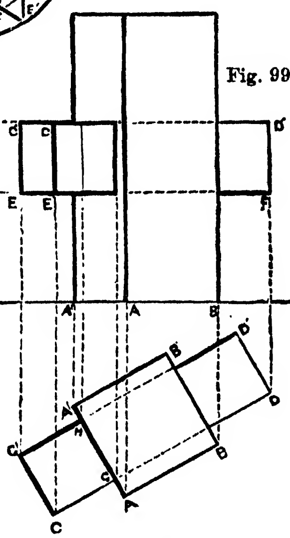


Fig. 99.

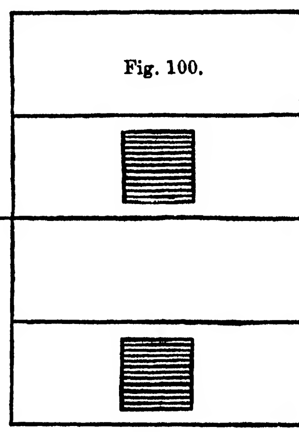


Fig. 100.

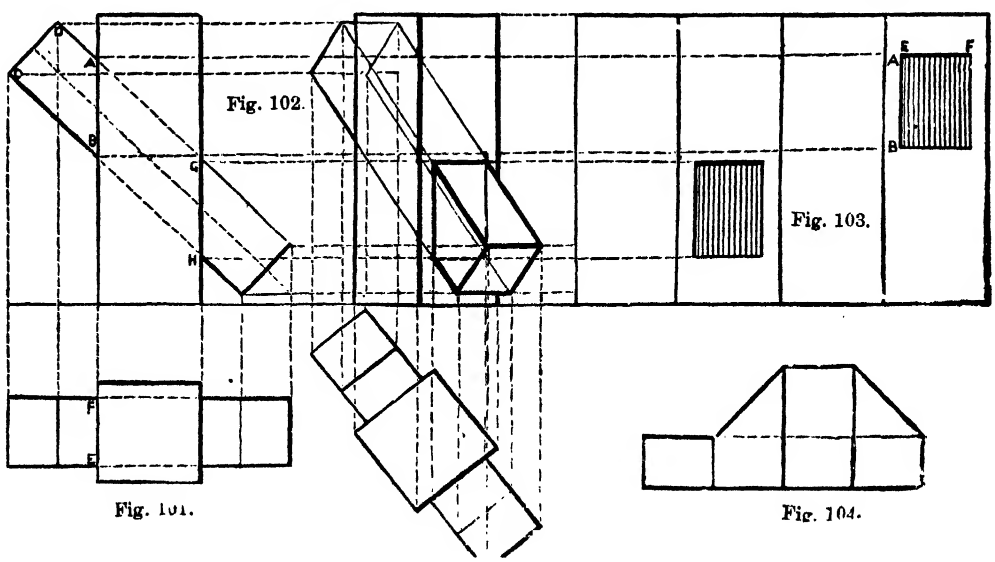


Fig. 101. Fig. 102. Fig. 103. Fig. 104.

ELECTRICAL ENGINEERING.—VII.

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PRIMARY BATTERIES.

RESISTANCE IN BATTERIES.

WHEN a current flows through a voltaic cell, the strength of that current (or the quantity of electricity generated by the cell in any time) depends upon two things. It depends upon the pressure with which it is forced through the cell, or, in other words, upon the electro-motive force (E.M.F.), and it also depends upon the *resistance* which is opposed to the flow of the current.

Returning to the water analogy, let us consider how the quantity of water which would flow in a given time from the higher to the lower reservoir would be affected by the conductor through which the water flowed. If the reservoirs were connected by a short, straight, smooth pipe of very large diameter, there would be a very large flow of water; but if they were connected by a very long, rough, narrow pipe with many sharp bends, it is clear that though the water would be forced through this pipe with the same pressure as through the thick one, the quantity which would manage to pass through would be considerably diminished; the resistance offered by the narrow pipe controls the rate at which the water flows through it. An exactly similar state of things exists in the case of the voltaic cell; the current is forced through the cell with a certain E.M.F.; but the strength of the current will depend upon the *resistance* opposed to its flow. As has been already said, no substance conducts electricity perfectly; expressed in another form, this means that every substance opposes some resistance to its flow. The metals in the cell offer comparatively little resistance; that of the liquid being the principal resistance which the current has to pass through. The resistance of any cell can be increased by increasing the distance between the plates, or by diminishing their size; and can be decreased by diminishing the distance between the plates, or by increasing their size. This resistance is a most important factor in any cell, as upon it depends the strength of current which it is possible for that cell to supply.

UNITS OF CURRENT, E.M.F., AND RESISTANCE.

In dealing with voltaic cells we have now to consider three things: the current, the electro-motive force, and the resistance; and it is advisable to express each of them in their proper units. We are in the habit of speaking of distances, times, weights, etc., in terms of some unit peculiar to each. The unit of distance or length we call a yard, the unit of time the second, the unit of weight the pound; and without some such system of units, with which every one is thoroughly acquainted, it would be impossible for people to interchange any definite ideas involving in a quantitative sense, length, time, or weight. Similarly in electricity it is necessary to have a unit of current, a unit of E.M.F., and a unit of resistance.

The unit of Current is called the AMPÈRE.
" " E.M.F. " " VOLT.
" " Resistance " " OHM.

A few examples drawn from the most common applications of electricity may give some clearer ideas as to the dimensions of these units:—

About three-quarters of an AMPÈRE is the usual *current* for the ordinary twenty-candle power *incandescent* lamp. About ten AMPÈRES is the usual current for the large *arc* lights.

The electro-motive force of the zinc and copper cell of which we have been speaking is about one VOLT. The E.M.F. required to light the ordinary twenty-candle power incandescent lamp is about 108 VOLTS. The E.M.F. necessary for the arc lamp is about 50 VOLTS. The E.M.F. of each of the accumulators in general use is about two VOLTS.

A copper wire 500 yards long and one-eighth of an inch in diameter has a resistance of about one OHM. The *resistance* of one mile of ordinary telegraph wire is about 13 OHMS. The resistance of a twenty-candle power incandescent lamp when hot is about 150 OHMS.

OHM'S LAW.

These three quantities—current, E.M.F., and resistance—are connected by a law due to Dr. Ohm, which is universally known as OHM'S LAW. It may be stated thus:—*The current flowing in any circuit is equal to the E.M.F. divided by the resistance in that circuit.* Or it may be stated thus:—

$$= \frac{\text{E.M.F. expressed in volts}}{\qquad}$$

s.

Or, putting it in its most convenient form and using symbols:–

$$C = \frac{E}{R}$$

Where C = the current expressed in ampères.
E = " E.M.F. " volts.
R = " resistance " ohms.

The above expression for Ohm's law can, of course, also be written in the form

C

So that when we know any two of the three quantities we can in every case determine the third by calculation. Taking an example, let it be required to determine what current a battery whose E.M.F. is 100 volts can send through a resistance of 20 ohms.

By Ohm's law $c = \frac{E}{R}$

but E = 100 volts, and R = 20 ohms. Putting in these values in the equation, it becomes

$$c = \frac{100}{20}$$

c = 5 Ampères ANSWER.

And in an exactly similar manner the E.M.F., or resistance, can be calculated when the other two quantities in the above equation are given.

CHEMICAL ACTIONS IN THE CELL.

Returning to the simple voltaic cell which we were considering in the last chapter (p. 148), it becomes necessary to thoroughly examine the chemical re-actions which took place in it as the current was being generated and the zinc burnt up. If the zinc be chemically pure (or what will answer quite as well, if it be a piece of ordinary commercial zinc thoroughly amalgamated with mercury), no action of any kind will take place in the cell till the plates are joined outside the liquid by the conducting wire—this operation is called "completing the circuit"—when the current will begin to circulate, and the zinc to burn away. The burning of the zinc is its uniting with the sulphuric acid in the cell to form sulphate of zinc, while at the same time hydrogen is given off on the surface of the copper plate. Sulphuric acid is a compound consisting of two parts of hydrogen (H), one part of sulphur (S), and four parts of oxygen (O), and is denoted in chemical language by the symbols H_2SO_4, which indicate its composition. Zinc is denoted by the symbol Zn, and sulphate of zinc (a compound of one part of zinc, one part of sulphur, and four parts of oxygen) by the symbols $ZnSO_4$. The re-action in the cell is then expressed by the equation

$$\underset{\textit{Zinc}}{Zn} + \underset{\textit{Sulphuric acid}}{H_2SO_4} = \underset{\textit{Sulphate of zinc}}{ZnSO_4} + \underset{\textit{Hydrogen}}{H_2};$$

or by the words, zinc and sulphuric acid unite to form sulphate of zinc, and hydrogen is set free.

LOCAL ACTION.

If a stick of chemically pure zinc be immersed in dilute sulphuric acid, no chemical action whatever takes place; but if a stick of common commercial zinc be subjected to the same ordeal, the result will be different; a brisk chemical action at once begins, hydrogen bubbles are freely given off on the surface of the zinc, portion of the sulphuric acid is turned into sulphate of zinc, and the zinc itself is burnt away, giving out a certain amount of heat. This difference between the passive state of the pure zinc and the active state of the common zinc is then clearly due to the impurities in the latter. These

impurities usually consist of iron, arsenic, chips of coke, or even slight inequalities in the zinc itself. When one of these impurities is on the surface of the zinc and in contact with the acid, all the conditions are satisfied for the generation of a current. The zinc acts as the fuel, the impurity as the negative element, and the consequence is that local currents are formed all round the foreign particle. As similar local currents are formed round every impurity, and as fresh impurities are being constantly exposed by the dissolving of the zinc, the *local action* (as this phenomenon is called) continually increases till the zinc all becomes burnt up.

Local action can be prevented by amalgamating the surface of the impure zinc. This can be done by first dipping the zinc in dilute sulphuric acid to clean it, and then rubbing mercury over its surface with a piece of rag tied on the end of a stick. A homogeneous zinc surface is thus exposed to the action of the acid, and the impurities are brought to the surface and carried off by the hydrogen bubbles. A still better plan is to mix about 4 per cent. of mercury with the zinc when casting it.

THE ALIMENT.

Action will continue to go on in the cell—if the circuit remains completed or closed—until either all the zinc gets burnt up or until all the sulphuric acid becomes converted into sulphate of zinc, or, as it is technically described, until the acid becomes *killed*. But long before arriving at this latter stage the action of the cell has gradually been getting weaker and weaker, until the time arrives when the sulphuric acid is nearly exhausted, when the action almost ceases, owing to the zinc not being in contact with the liquid with which it tends to unite.

Let us once more compare the action of the cell to the burning of an ordinary coal fire, and see how nearly identical the two operations are. A fire ceases to burn or to give out heat when one of two things happens: when the coal becomes all burnt up, or when all the available air has united with the coal; in other words, when the supply of air has been exhausted. The air plays the same part relative to the coal which the sulphuric acid does to the zinc. The name *aliment* will in future be used for that substance with which the fuel unites in order to give up its energy, whether in the form of heat or electricity. In a voltaic cell the amount of the aliment is usually a fixed quantity as the cell can only hold a fixed quantity of acid; but in the case of the fire, under ordinary circumstances, the supply of the aliment is unlimited. In order to make the two cases exactly similar, the fire should be lighted in an air-tight room, when it would cease to burn as soon as it had exhausted all, or nearly all, the original supply of air which was in the room.

It is a fact within every one's experience that if a fire be supplied with different aliments, or with different amounts of the same aliment, the fierceness with which it burns—or the temperature to which the coal is raised—largely depends upon the aliment, and the quantity of that aliment, with which it is supplied. If the fire is in a closed room it burns feebly; if it is in connection with a tall chimney, or if air is forced through it by means of a bellows or some such arrangement, it burns quite fiercely, giving out much heat. If instead of air it had been supplied with pure oxygen, or, better still, with chlorine gas, its temperature would have been considerably raised, and the fierceness of combustion much augmented. In the voltaic cell an exactly similar state of things exists. If the aliment sulphuric acid be replaced by bichromate or permanganate of potash, the zinc will be burnt up much more quickly, which means that the E.M.F. of the cell is raised. The E.M.F. of the cell corresponds to the temperature of the furnace. In the furnace temperature is the force which does work; in the cell E.M.F. is the force which does work.

POLARISATION.

Having dealt with the first portion of the chemical action it now remains to see what part the hydrogen plays in the subsequent working of the cell. As has been said, this hydrogen is all given off on the surface of the copper, and in consequence the copper plate soon becomes completely covered with a thin layer of hydrogen gas. Any further action in the cell only generates hydrogen bubbles, which, starting at the copper, rise through the liquid and go off in the atmosphere. This layer of hydrogen plays two parts in the working of the cell, both of which are distinctly bad: it increases the resistance of the cell by interposing a layer of gas in the path of the current (gas has a very high resistance); but its second effect is far worse, it reduces the E.M.F. of the cell. When the copper plate becomes completely covered by this layer, it no longer acts as if it were copper. The sulphuric acid is no longer in contact with copper, it is in contact only with the layer of hydrogen, and it is this hydrogen which is now the negative element in the cell. The fact of the surface of the copper being coated with hydrogen makes the plate act as if no other metal but hydrogen formed the negative element. Reference to the table of heat-values of the different metals in the previous chapter (p. 147) furnishes the complete explanation of the reason why the E.M.F. is reduced. It will be remembered that the E.M.F. of a cell depends upon the difference between the heat-values of the metals used—

This difference for *zinc* and *copper* is 23,940
" " *zinc* and *hydrogen* is 8,700

which is little more that one-third of the previous difference; and it is found in practice that when this layer of hydrogen has once formed, the E.M.F. of the cell falls to a little more than one-third of its original value. This phenomenon has received the name of *polarisation*, and when the copper plate has become covered with hydrogen the cell is said to be *polarised*.

CLASSIFICATION OF CELLS.

The necessity for avoiding polarisation in a cell is so obvious that countless remedies have been suggested for getting rid of this injurious deposition of hydrogen on the negative element. These remedies, though differing in detail, all come under some one of three general principles; so important, in fact, is the part played by the phenomenon of polarisation in primary batteries that it seems the most convenient, if not the most scientific method of classification, to group them according to the methods used to prevent polarisation. Adopting this plan, they may be divided into the four following classes:—

I. Cells in which no attempt is made to prevent polarisation;

II. Cells in which polarisation is prevented by mechanical means;

III. Cells in which polarisation is prevented by purely chemical means;

IV. Cells in which polarisation is prevented by electro-chemical means.

TECHNICAL DRAWING.—XI.

DRAWING FOR CARPENTERS AND BUILDERS.

DEVELOPMENT OF THE SURFACES OF ROOFS.

ALTHOUGH the whole subject of the development of prisms is treated in lessons on "Projection," it is deemed desirable to give two examples here, showing the immediate application of the principles to roofs, in order to enable the student to find the exact shapes of the surfaces of which they are composed; and, as in the case of a hipped roof, the length of the hip-rafters.

Fig. 82.—In this figure, *a b c d* is the plan of the building to be covered with a hipped roof.

To draw the plan of the roof, bisect the angles of the parallelogram, and the bisecting lines meeting in *e* and *f* will form the plans of the hip-lines, and the line joining *e* and *f* will be the plan of the ridge.

It is now required to project the elevation from this plan. To do this, draw any horizontal line, as A B (Fig. 83), and the perpendiculars from *c*, *e*, *f*, *d*, cutting A B in *g*, *h*, *i*, *j*, and produce *h* and *i* indefinitely.

Produce the perpendicular at *e* until it reaches *l*; then it will be clear that *k l* is the width of the roof-trusses (at *k l* and *m n*), which would be at right angles to the sides *a b* and *c d*.

Draw *k′ l′* (Fig. 84) equal to *k l* in Fig. 82, and at the middle point, *o*, draw the perpendicular, *o p*, equal to the *real* height of the truss, which is, of course, a matter dependent on the design of the architect. This triangle, then, will be the shape of the truss at this point, and is the section *across* the roof.

Make *h q* and *i r* in Fig. 83 equal to *o p* in Fig. 84; draw *g q*, *q r*, and *r j*, which will complete the elevation; and this will also be the longitudinal section through the ridge.

We now have to find the real length of the hip: to do this

draw $f\,s$ (Fig. 82) equal to $o\,p$ (Fig. 84), and at right angles to $f\,d$; join $d\,s$; then the right-angled triangle $d\ f\ s$ is the true shape of the hip-truss. This will be understood by cutting a piece of cardboard of this shape, and placing it on its edge on $d\,f$, then it will be seen that $d\ s$ will be the length of the hip.

To develop the covering of this roof:—It will, of course, be then the trapezoid $c\ v\ w\ d$ is the development of one of the planes forming the side of the roof-covering. The same length set off on the perpendiculars l, n will give the points x, y, which will complete the fourth plane.

We will now proceed to find the form of the hip when the roof is a groined one.

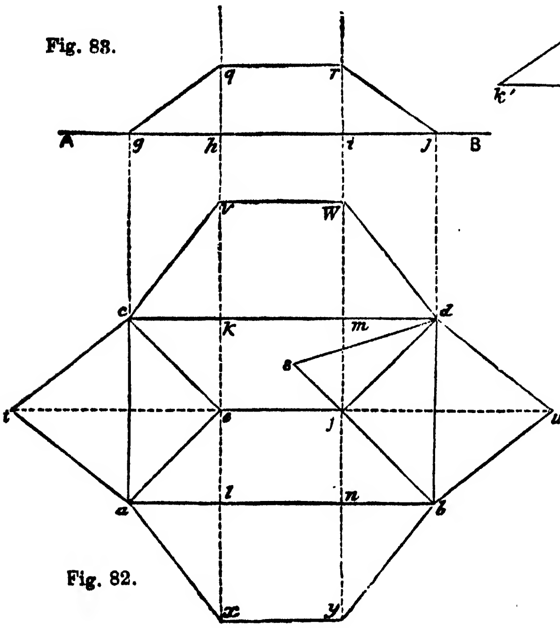

Fig. 83.

Fig. 82.

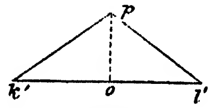

Fig. 84.

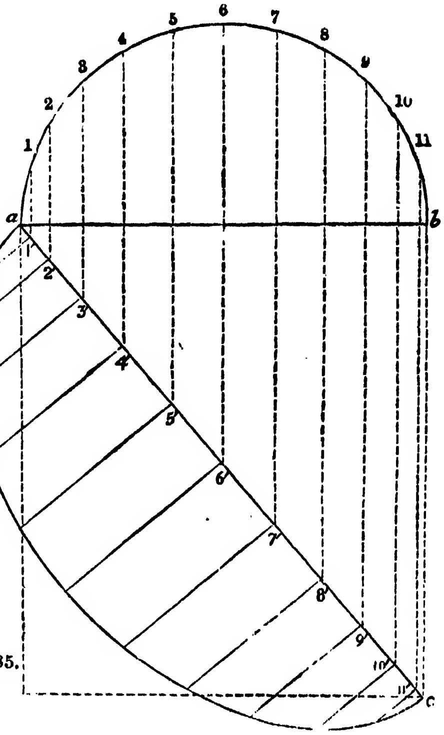

Fig. 85.

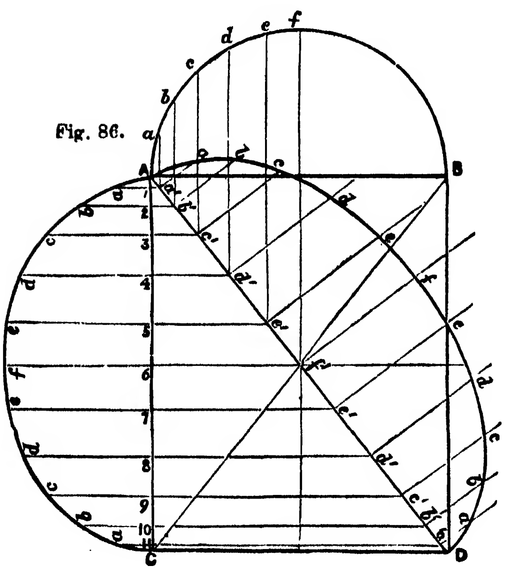

Fig. 86.

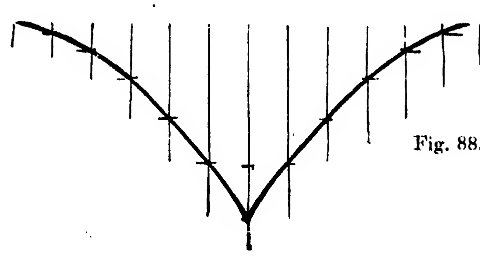

Fig. 88.

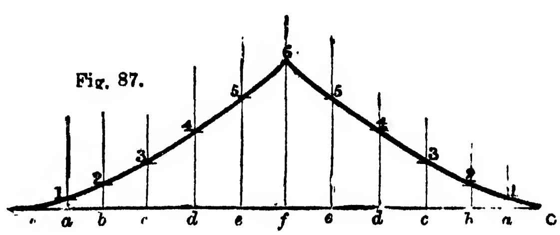

Fig. 87.

understood that this will consist of four planes, which will meet at the hip-lines. Now, it has already been shown that the ends are triangles, of which $a\ e\ c$ and $b\ f\ d$ are the plans; the length of lines $a\ c$ and $b\ d$ remains unaltered, but the *real* length of $c\ e$, $a\ e$, $b\ f$, and $d\ f$ has been proved to be $d\ s$; therefore on $d\ b$ and $a\ c$ construct isosceles triangles, having $d\ s$ for the two remaining sides; these triangles then, $a\ t\ c$ and $b\ u\ d$, are the true shape of the coverings of the ends of the roof.

Now from c and d, with radius $c\ t$, describe arcs cutting the perpendiculars k and m in v and w; join $d\ w$, $v\ c$, and $w\ v$;

Let me ask you to imagine yourself standing on the platform of a railway at the side of a semi-circular arch by which a road is carried over it; you will then see that whilst the face or elevation of the arch where it crosses the railway at right angles is semi-circular, its span being of course the diameter of the circle of which it is the half, the length from the springing near which you are standing, to the most distant springing (that is, the one on the opposite side of the line at the other end of the arch) will be much longer; yet the arch there *is not any higher*, although its span thus taken crosswise is longer,

because the diagonal of a square or other rectangle is longer than either of its sides. The principle on which to find the shape of the curve which would reach from the springing at which you are standing to the one referred to, is also shown in Fig. 85.

On *a b* describe a semicircle, and divide it into any number of equal parts in the points 1, 2, 3, 4, etc. From these points let fall perpendiculars on *a b*, and produce them downwards till they cut the diagonal *a c* in the points 1′, 2′, 3′, 4′, etc. Now, from the points where the lines 1′, 2′, 3′, 4′, etc., cut *a c*, draw lines perpendicular to *a c*; make each of these equal in height to those correspondingly lettered in the semicircle, and the curve drawn through their extremities will be the form required.

Fig. 86.—Here A B C D is the plan of a building to be covered by a groined roof.

The arch, the springing of which is A C and B D, is a semi-cylinder.

The arch which has its springing in A B and C D, being of the *same height* but of wider span, is a semi-*cylindroid.*

A cylindroid is a solid body of the character of a cylinder. But whilst in a cylinder all sections taken at right angles to the axis are circles, in the cylindroid all such sections are *ellipses.* It is, in fact, a flattened cylinder.

The curve at the groin, then, is generated by the penetration of a cylindroid and cylinder.

On A B describe the semicircle which represents the form of the arch at the ends A B and C D, and divide it into any number of equal parts, *a, b, c,* etc. It is only necessary to use the quadrant, as throughout the working the measurements are the same on each side.

Draw the diagonals A D and B C.

From *a, b, c, d, e, f* draw lines perpendicular to A B, and cutting the diagonal A D in *a′, b′, c′, d′, e′, f′,* and set off the same distances on the other half of the diagonal.

From these points draw lines at right angles to A C, and passing through it in points 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11; mark off on the perpendicular 6 the height of 6 *f* equal to the height of the semicircle *f*, and on the perpendiculars 5, 4, 3, 2, 1 mark off in succession the heights of the perpendiculars *e, d, f, c, b, a,* as contained between the semicircle and the *diameter.* Set off the same heights on the corresponding perpendiculars on the other side of 6 *f*, and the curve traced through these points will be a semi-ellipse, which is the section of the semi-cylindroid forming the arch of which A B and C D are the springings.

We now proceed to find the curve of the groin; and it will be evident that, although the span is still further increased in length, the heights of the different points in the curve will be the same as in both the previous elevations.

The span, then, of the arch at the groin is the diagonal A D (or B C), to which the divisions *a′, b′, c′, d′, e′, f′* have already been transferred from the semicircle, and from these the lines were carried at right angles to A C, on which the heights of the points in the curve were set off.

These points on the diagonal, then, will be seen to be common to both arches, since they are the plans of the points in the roof where the cylindrical and cylindroidal bodies penetrate each other. At these points, therefore, draw lines perpendicular to the *diagonal,* and mark off on these the heights of the perpendiculars in the semicircle from which the points on which they stand were deduced. These extremities being connected, the curve so traced is the groin curve, and will give the shape for the centering for the groin, as the semi-circle and semi-ellipse will for those used in the elevations of the arches.

It now only remains to develop the soffits or under surfaces.

Fig. 87.—Draw any straight line, and commencing at A set off on it the distances into which the curve A C is divided (measuring on the *curve, not* on the springing-line), namely, the distances A *a, a, b b, c c,* etc.

At the points on the straight line thus marked, draw perpendiculars; make the middle one equal to 6 *f*, those on *e, e* equal to 5 *e*, those on *d, d* equal to 4 *d*, those on *c, c* equal to 3 *c*, those on *b, b* to 2 *b*, and those on *a, a* equal to 1 *a*. Join the extremities of these perpendiculars, and the two curves meeting in a point, and joined by the original straight line, will form the development of the soffit of the cylindroidal arch.

Fig. 88 is the development of the semi-cylindrical arch. As this is worked in precisely the same manner from the *semicircle,* no further instructions are deemed necessary.

Fig. 89.

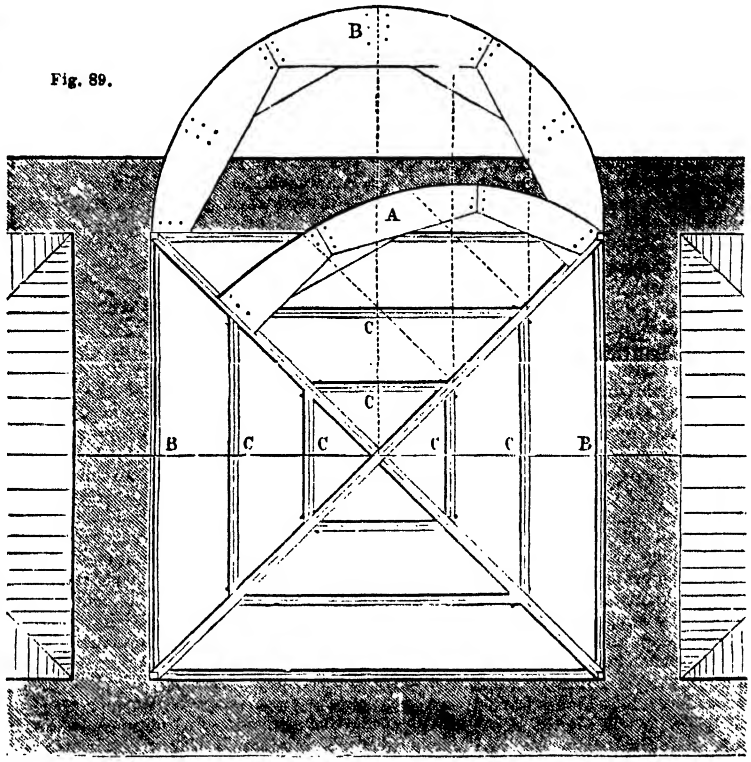

Fig. 89 is the plan of a building to be covered by a roof of a pyramidical form, the hips, however, being *curved* instead of straight, so that the roof is really a square dome.

Now in this case, the given rib crossing from B to B, and that which would cross it at right angles through the centre, is shown at B, which is the form of wooden centering which would be used to divide the semicircle into any number of equal parts. Draw diagonals in the square, and from the divisions in the semicircle draw lines perpendicular to the diameter, and cutting the diagonal; at these points erect perpendiculars, and make them equal to those in the semicircle; then the curve drawn through their extremities will be the shape of the hip. This is shown lying down in the illustration, and the student is advised to cut the form in cardboard, when by standing it on its edge against a semicircle placed on the line B B, he will be able thoroughly to comprehend the difference between the forms caused by their positions.

When a roof is constructed as in this figure, but the curve is truncated, or cut short by a flat surface, it is called "coved and flat."

Ceilings are sometimes built in this manner. They form a sort of compromise between a flat ceiling and the various arched forms practised by the ancients. They do not require so much height as the latter mode, and have therefore been of considerable use in the finishing of modern apartments; but although the form is admired by many, it naturally is wanting in the elegance and grandeur of entire arched ceilings, nor does it admit of that beauty of decoration of which they are susceptible.

AGRICULTURAL CHEMISTRY.—IV.

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CHAPTER IV.—FORMATION AND COMPOSITION OF SOILS.

THE solid "crust" of the globe is composed of substances termed *rocks* by the geologist, whether they exist in the enormous compact masses popularly known as *rocks*, or in the slightly coherent states called clay, gravel, sand, etc. Granite, gneiss, trap, basalt, sandstones, limestone, and various other minerals, constitute the solid rocks. They are composed of the metals potassium, sodium, magnesium, calcium, aluminum, and iron, united with the metalloids (non-metals) oxygen, carbon, silicon, sulphur, and phosphorus. The metal manganese occurs also (and very commonly) in rocks, but only in small quantities; and the metals barium and strontium are also occasionally found in masses of rock. Fluorine combined with calcium (fluoride of calcium, or fluor spar) is also met with in rocks, but in comparatively minute quantities. The great bulk of rocks is made up of the elementary substances silicon, oxygen, carbon, aluminum, and calcium.

Silica, or silicic acid, is composed of 46·7 parts of silicon combined with 53·3 parts of oxygen. It constitutes the great bulk of most kinds of rock, such as granite, gneiss, and basalt, and it is the chief constituent of such common minerals as felspar, mica, hornblende, and meerschaum. Quartz, flint, rock crystal, jasper, chalcedony, and agate are varieties of silica.

Aluminum is a white, malleable metal, about one-third the weight of silver. It is but very slightly affected by the air. 53·39 parts of this metal combined with 46·61 parts of oxygen constitute the earth alumina. The latter, when artificially prepared, is a white substance, insoluble in water, but possessed of a great tendency to combine with that liquid. The intensely hard mineral corundum is pure alumina; and emery, and the beautiful gems termed the sapphire and the ruby, are slightly impure varieties of this earth. The plastic constituent of clays and porcelain earths is alumina; and this body is the basis of bricks and pottery. The affinity which alumina has for moisture may easily be proved by applying the tongue to a brick or piece of unglazed porcelain.

The metal calcium, united with oxygen in the proportion of 71·43 parts of the former with 28·57 parts of the latter, constitutes the earth lime, or calcic oxide. This body is white, and is about three times the weight of water. When water is poured upon lime, they combine, the earth swells up, and (unless there be too much water) crumbles into a fine powder. During this process a large amount of heat is evolved. This compound of water and lime is termed *slaked lime*, or calcic hydrate (formerly, hydrate of lime), and is largely employed as an ingredient of mortars and cements. Limestone and marble are essentially composed of lime, or calcium in union with carbonic dioxide. When either mineral is highly heated, carbonic dioxide is expelled, and calcic oxide (quick or burnt lime) remains. The important earthy salt gypsum, or plaster of Paris, is calcic sulphate; and tricalcic diphosphate is one of the most valuable earthy compounds used in agriculture. A large number of minerals containing tricalcic diphosphate exist, and are employed for agricultural purposes.

The metal magnesium occurs far less abundantly than calcium. 60·28 parts of this metal and 39·72 parts of oxygen form the earth magnesia—a bulky, white, tasteless powder. Dolomite is a compound of calcic carbonate and magnesic carbonate, and the well-known Epsom salts are magnesic sulphate. Magnesium occurs in all fertile soils, and in a great variety of minerals, such as, for example, chrysolite, French chalk or steatite, meerschaum, serpentine, and asbestos.

Geologists have not been able to penetrate very far beneath the surface of the earth; consequently, the composition of all but the mere skin, so to speak, of our globe is unknown to us. So far as we have penetrated, certain kinds of rocks have been found in layers or beds termed *strata*, overlying each other in regular succession. Occasionally the strata have a horizontal direction, but more frequently they form angles with the surface of the earth.

The stratified* rocks are termed *aqueous*, because it is believed that they have been formed out of older rocks by the action of water. The hardest kinds of rock crumble away under atmospheric influences, and the *débris* or fragments become transported to considerable distances by means of drainage water, rivulets, rivers, the sea, and even by glaciers and icebergs. The pulverised particles of rock deposited in various places out of water undergo a kind of cementation and form new rocks. The latter, being produced from a gradually-deposited sediment, necessarily have a stratified or leaf-like structure. Some stratified rocks are derived from the remains of animals. Chalk and limestone are composed chiefly of the remains of shell-fish and other animals. So great is the rock-forming power of large rivers that, according to Sir Charles Lyell, the Nile annually deposits 3,702,758,400 cubic feet of solid earthy matter beneath the waters of the Mediterranean. The greater part of Egypt was believed by Herodotus to be "the gift of the Nile."

The rocks termed *igneous* are those which have been subjected to, or formed under the influence of, intense heat. They are generally composed of small crystals or vitreous (glass or slag-like) substances. They generally underlie the stratified rocks, but often pass up through the latter in a wedge-like form. Granite and trap are igneous rocks, and lava, or other volcanic rocks, also belong to this group, and are the latest members of it. Limestone, oolite, and sandstones are familiar examples of stratified rocks. Rocks intermediate between aqueous and primary rocks are termed *metamorphic*: gneiss is a metamorphic rock. Fig. 7 shows the appearance presented by a vertical section of stratified rocks.

Fig. 7.—SECTION OF STRATIFIED ROCKS.

The greater portion of the surface of the "dry land" is covered with loose fragments of rocks, mixed with the remains, more or less altered, of plants and animals. These matters are termed *soils*, and they extend downwards to distances varying from an inch to more than twenty feet. There are two kinds of soil, the *super* and the *sub*. The former term is confined to the layer next the surface, which contains nearly all the organic matter (*i.e.*, animal and vegetable substances), and throughout which the roots of plants ramify. The sub-soil generally closely resembles the super-soil so far as their mineral ingredients are concerned, but the condition in which these ingredients exist is somewhat different in the two soils.

Both super- and sub-soils are often formed by the disintegration of the hard rocks underlying them; but sometimes they are produced from the *débris* of rocks transported by aqueous agency from distances more or less considerable.

The agencies which form soils are frost, rain, damp, oxygen, and carbonic dioxide. Water, when it is converted into ice, expands about 10 per cent. of its volume. In the densest rocks there are little cavities containing water, which in winter often expand with irresistible force into ice, and thereby increase the size of the cavity. This process, carried on for centuries, produces the disintegration of enormous quantities of rock. The mere mechanical action of rain and hail upon rocks also crumbles away in process of time the densest stone surfaces—witness the rough and decayed aspect presented by so many of our stone buildings. Carbonic dioxide has a great affinity for potassium and sodium; and as these metals are common ingredients of rocks, they are often abstracted from them by the free carbonic dioxide of the atmosphere—a circumstance which renders the rocks more porous and friable. The ferrous oxide (protoxide of iron) in rocks is often converted into ferric oxide (per- or sesqui-oxide) by the atmospheric oxygen, and this process tends to break up the structure of the rock. The influences of air and moisture upon the solid crust of the globe are, of course, confined to the surface, and take place with an extreme degree of slowness; but influences, however small, exerted during a considerable period of time, ultimately produce great effects. The stratified rocks (which include soils) now in existence have been produced by the atmospheric influences of countless ages. It is, indeed, probable that, as Liebig remarks, the atmospheric influences of a

* From the Latin *stratum*, a layer, and *facere*, to make.

thousand years are necessary to form from any kind of rock a layer of arable soil one-twelfth of an inch thick. suitable for the growth of plants.

The composition of soils varies greatly. Some contain considerable amounts of calcic carbonate, others are very rich in organic matter, whilst many are composed of but little more than silica. As a rule, silica is by far the most abundant mineral ingredient of soils; next comes alumina; and ferric oxide and calcic carbonate are about equally abundant. The following is the composition, according to Voelcker, of a sandy soil (Tubney Warren, Abingdon), deficient in lime, alkalies, and phosphoric acid. 100 parts of the dried soil contain—

Organic matter	5·88
Oxides of iron, and alumina	4·11
Carbonate of lime (calcic carbonate)	0·62
Magnesia	0·22
Potash and soda	0·14
Phosphoric acid	0·07
Sulphuric acid	0·04
Insoluble silicious matter (fine sand)	88·92
	100·00

The amount of silica is generally from 80 to 94 per cent. in sandy soils, from 70 to 80 in clay lands, from 60 to 70 in loams and rich moulds, from 40 to 60 in marly clays, from 5 to 40 in calcareous or limy soils, and in marls.

The proportion of alumina is greatest in rich loams, but it rarely exceeds 15 per cent. In clay soils alumina exists on the average to the extent of about 7 per cent.; in sandy soils its per-centage varies from 1 to 5. Marls, calcareous soils, and vegetable moulds contain from 1 to 8 per cent. of alumina. The larger the proportion of alumina in the soil, the more difficult is its cultivation—the adhesive character of the earth offering a stubborn resistance to the passage of the plough and the spade through it. Porcelain and brick clays contain from 30 to 40 per cent. of alumina.

The per-centage of calcic carbonate varies from 90 per cent. in the case of marls and limestone soils to mere traces. Clays and loams generally contain from 1 to 3 per cent. of this substance. Less than 1 per cent. may be regarded as a defective proportion.

Potash exists in soil from the merest trace to nearly 3 per cent. Soils rich in alumina are, with rare exceptions, also rich in potash. Sandy and peaty soils and marls are in general deficient in this alkali.

Soda is not so important a constituent of plants as potash; and, except near the coast, it is not quite so abundant in soils as potash. Its proportion varies from a trace to 2 per cent.

Magnesia is found in all fertile soils, and in per-centages which range from ·05 to 1·5.

Marly, peaty, and calcareous soils contain very minute amounts of phosphoric acid, but in clays its per-centage is occasionally 1·5. In general, even very fertile land contains less than 1 per cent., and the average amount is probably about 0·4 per cent.

Sulphuric acid and chlorine occur very sparingly in soils. Carbonic dioxide is abundant in all cases where there is much lime. It is generally found in the form of calcic carbonate and magnesic carbonate.

Organic matter (animal and vegetable substances more or less decomposed) is present in all soils capable of producing good crops. Sometimes, as in the case of bogs and peaty mosses, it is too abundant. It is most deficient in sandy soils, which often contain less than 1 per cent. of this ingredient. Cold clays are in general poor in organic matter. Fertile loams include from 10 to 14 per cent. of this valuable element of fertility.

BUILDING CONSTRUCTION.—VI.

BRICKWORK (*continued*).

FOUNDATIONS.

Having in the previous lesson shown the difference between English and Flemish bonds, we now purpose illustrating the method by which these may be worked together.

Figs. 30 and 31 show plans of first and second courses of a wall in which the front is built in Flemish and the back in English bond. This is considered a good wall, but still possesses the disadvantage of half-bricks. And thus it will be seen that in the one course the front line of bricks, and in the other the back line, is totally unattached to the rest; whilst in Figs. 28 and 29 the headers penetrate two-thirds into the thickness of the wall.

Flemish bond has been much used in situations where the walls were not to be covered with stucco, for the reason already assigned, viz., its neat appearance. But in every case where the greatest strength and compactness are required the English bond is preferred, in consequence of its admitting of more transverse bonding than the other. Flemish bond was introduced into this country in the time of William and Mary; but why it has received the name it bears does not seem to be known; for in Flanders, Holland, Rhenish Germany, etc., this system is not by any means generally practised, the style which we call old English bond being almost universally adopted.

A third kind of bond is sometimes used with the view of strengthening very thick walls. This mode consists in laying the bricks which fill up the core, or space between the front and back surfaces, diagonally or angle-wise, their direction being reversed in each course. This is called a *rake*, and does away with the necessity for using half-bricks in the heading course; but, of course, it leaves triangular interstices at the points where the angles of the bricks in the core meet the straight faces of the external facings of the wall.

Fig. 32 represents the plan of a three-brick wall built in this manner. It will be seen that the connection between the faces and the core is but very imperfect. The external faces consist of alternate courses of headers and stretchers, the core being filled up by a raking course. This course rests on and is also covered by a complete course of headers, and each time it occurs the direction of the bricks is reversed.

Fig. 33 is the plan of a wall similarly constructed, called *herring-bone* bond. In this mode also, courses of headers would bed and cover the herring-boning, and the direction of the bricks in the core, like in the last, is reversed in each course. It will be noticed that this plan leaves a central line of squares to be filled up by half-bricks, in addition to the triangular pieces used at the sides.

Neither of these two systems should be used for any but very thick walls.

Perfect accuracy in bricklaying, as indeed in all mechanical arts, cannot be too much impressed on the artisan; and this should be carried out not only in the parts of a structure which are visible, but in those which may be hidden. For instance, it is of the utmost importance that all the joints in brickwork should be perfectly plumb or vertical, and that every course should be absolutely horizontal, both lengthwise and across. The *lowest* courses of a brick wall should be laid with the strictest attention to this particular; for, as all the bricks are of the same thickness, any irregularity will be carried up throughout the whole wall, and the workman will then attempt to rectify it, or to "level it up," by using more mortar in some parts than others; but, of course, mortar whilst wet is to a certain extent compressible where bricks are not, and there will thus be unequal settlement, which will subsequently not only impair the appearance, but endanger the safety of the wall, and possibly of the entire structure. In order to save the trouble of constantly applying his rule and level to the work, the bricklayer, when he has got beyond the footings or foundations, builds up three or four courses at the ends of the wall, as at A and B (Fig. 34). These he very carefully plumbs and levels across; he then strains a line from one end to the other, and this guides him as to the level of his course; but if the distance be long, the line will sag or hang slightly downward in the middle, and to prevent this, occasional bricks are placed which serve to support it, as shown at C. When the work has been carried up three or four courses, it should, however, be tested with the plumb-rule and level. In bricklaying, the workman spreads the mortar over the last course with his trowel, so as to form a bed on which the brick may rest. As any mortar spreads beyond the edge of the course, it is caught up on the face of the trowel, and is put up against the vertical end of the last brick laid in the new course. The bricklayer then with his left hand *lays* the brick, and presses it downwards until it is in its exact place in the line, sometimes striking it with the side of the trowel, or giving it a smart tap with the end of the handle. The small quantity of mortar thus pressed out between the

bricks is knocked off with the trowel, and the line smoothened with the point—that is, if it is to be seen; but on the inside of walls which are to be plastered, the rough projecting line of mortar is left, as it helps in attaching the plaster. It is advisable that bricks should be damp when they are being laid; for if their pores are full of air, and their surfaces covered with dry dust, the mortar will not adhere. This is generally done on the scaffold, for wetting them below would make them much heavier for the labourer to carry up, and many of them would

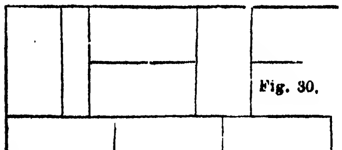


Fig. 30.

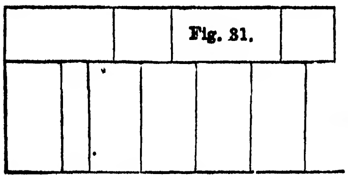


Fig. 31.

Fig. 36.

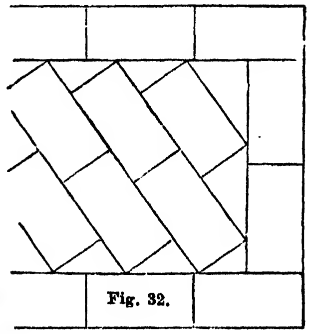



Fig. 32.

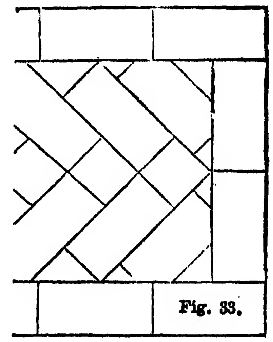


Fig. 33.

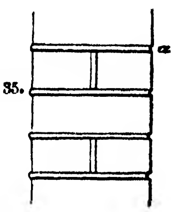
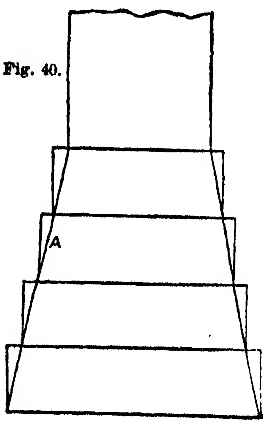


Fig. 35.

Fig. 40.


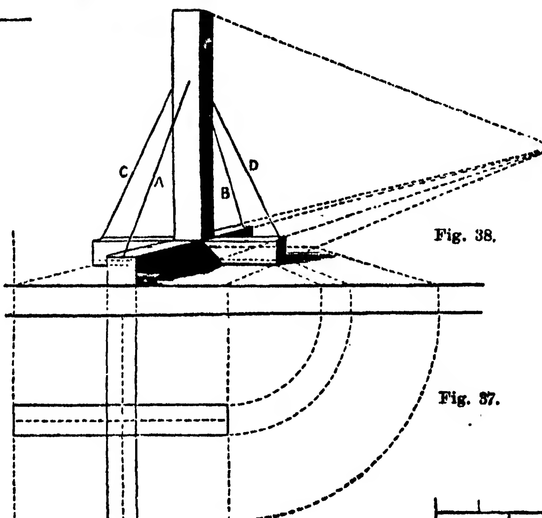


Fig. 38.
Fig. 37.

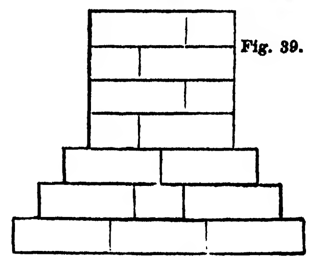


Fig. 39.

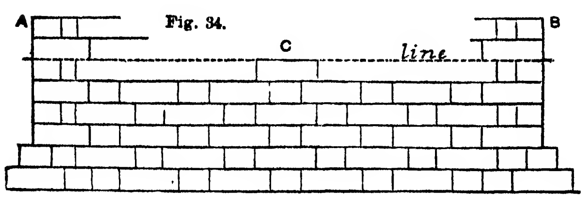


Fig. 34.

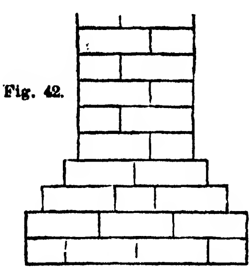
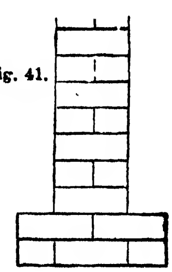
Fig. 42.


Fig. 41.


dry before wanted for use. They should, therefore, be dipped in water just as they are wanted, and this may be done by boys supplying them as required by the bricklayer.

The following remarks, taken from Mr. W. Hoskings' excellent work, are quoted, as from their exceedingly practical character they cannot fail to be of use to the artisan:—"As mortar is a more yielding material used in bricklaying for the purpose of making the detached portions of the staple adhere, by filling up their interstices and producing exhaustion—and the object being to produce as unyielding and consistent a mass as possible—as much of it should be used as is sufficient to produce the desired effect, and no more. No two bricks should be allowed to touch, because of their inaptitude to adhere to each other; and no space between them should be left unoccupied by mortar, which may produce adhesion. When the bricks are a fraction under 2½ inches thick, no four courses of bricks and mortar, or brickwork, should exceed 11 inches in height; and if they are fully that thickness, four courses should not reach 11½ inches. The result of thick beds of mortar between the bricks, is that the mortar is pressed out after the joint is drawn on the outside of the front, and being made *convex* instead of slightly *concave*, the joints catch every drop of rain that may trickle down the face of the wall, and thus become saturated; the moisture freezes, and in thawing bursts the mortar, which crumbles away, and creates the necessity, which is constantly recurring, of 'pointing' the joints to preserve the wall." Fig. 35 shows the section of a 9-inch wall with the joints on the side *a* as drawn, and on the side *b* as bulged out in consequence of the quantity of mortar in them yielding to the weight above. This, too, is in addition to the inconvenient settling which is the consequence of using too much mortar in the beds. In practice, bricklayers lay the mortar on the course last finished, and spread it over the surface with the trowel, without considering or caring that they have put no mortar *between* the bricks of that course—except

in the external edges of the outside joints. As the mortar is not, or ought not to be, so thin as to fall into the joints by its own weight, unless they press it down, half the space between the bricks remains in every case unoccupied; and the wall is consequently hollow, incompact, and necessarily imperfect. To obviate this it is common to have thick walls "grouted" in every course—that is, mortar made liquid, and called *grout*, is poured on, and spread over the surface of the work, that it may run in and fill up the joints completely. This, at the best, is but doing with grout what should be done with mortar; and the difference between the two consisting merely in the quantity of water they contain, mortar must be considered the best; for the tendency of grout is, by hydrostatic pressure, to burst the wall in which it is employed; and moreover, it must, by taking a much longer time to dry and shrink than the mortar of the beds and external joints, make and keep the whole mass unstable, and tend to injure rather than to benefit it. Filling, or flushing-up every course with mortar, is therefore far preferable, and may be done with very little additional exertion on the part of the workman.

So much having been said on the subject of settlement, it will be seen that owing to stones or bricks being united to each other by mortar, a certain amount of shrinking or settlement from this and other sources is certain to take place. The art of the builder must, however, be devoted to ensure *equal* settlement, and this can only be done, firstly by using the same thickness of mortar throughout, and secondly, by carrying up all the walls which are to sustain the same floor *simultaneously;* for, as all walls shrink immediately after building, the part which is first built will settle before the adjoining part is brought up to it, and the shrinking of the latter will cause the two parts to separate. The ends of the walls first built should be "racked back;" that is, left off slantingly as in Fig. 23, not merely "toothed" vertically as in Fig. 16.

Having thus explained the elementary principles of masonry and bricklaying, the subject of foundations can be proceeded with.

In foundations then, considered in relation to the walls, etc., of buildings, it is necessary to observe:—

1. That when the wind blows, or any other lateral force acts against a wall, etc., the higher it is the more powerful will be the leverage by which it acts against the point on which it rests, and the greater the danger of its being thrown over.

2. The narrower the base on which it rests, the more is it liable not only to be thrown over but to sink.

A timber construction will, perhaps, best serve to illustrate this.

Let Fig. 36 represent a stick of timber or square pole simply placed in the ground; it will be clear that it would be very liable to sink, or that the wind or any other force would be very likely to throw it down. We shall endeavour to treat each of these evils separately; and as these lessons aim at teaching not only *work*, but *thought*, let us earnestly impress on our young students the benefit arising from systematic thinking and action, and urge them before putting pencil to paper, or laying a single brick, to ask themselves: What do I want to do? what is the object to be accomplished? what is the best method of attaining this end? are the means I am taking the best, just because others use them? and if they *are* so, *why* are they so? These questions lie at the foundation of all progress and improvement; and it is through the habit of thus reflecting that an artisan rises above the level of a working *machine* to the dignity of a working *man*.

Let us see, then, what would be the best way to prevent the sinking of the pole, and it will at once be evident that this will be the best accomplished by widening the base. Of course this would be done by placing it on another stick of timber laid horizontally, but better still if two such pieces are placed in the form of a cross (Fig. 37); by this means a basis is formed which, to all intents and purposes, is equal to the complete square in which the cross could be inscribed, and therefore the pole rests, as it were, on a foundation equal to that area. Thus the sinking would be prevented. And now we can turn our attention to the second point, viz., the swaying of the pole, or the liability to be thrown over by any lateral (or side) force. This may be accomplished by mortising struts A, B, C, and D (Fig. 38) into it, and into the stand, in the direction of the single lines here given, and by this means the effect of the breadth of the base will be transmitted to the post. These struts will not only serve to steady the pole, but to relieve the pressure which would otherwise fall on its lower end, but which is thus shared by all the struts, and is by them spread over the whole base; and so fracture at the point where the whole weight would fall is avoided. This illustration has been worked by perspective, a study which will be treated of in other lessons.

In stone and brick walls, the foundations are formed by commencing the lower course wider than the intended thickness of the wall, and then gradually diminishing the breadth until the real size is reached. These projecting edges are called "footings" (Fig. 39).

In stone walls, where the weight falling on the foundation is very heavy, care must be taken that the offsets for footings are not too great in each course, as, owing to the natural brittleness of stone, fracture is likely to ensue; nor should the joints between the stones fall too near or beyond the face of the wall, as in that case they would be liable to yield under the superincumbent weight.

In cases such as the foundations of the piers of bridges, vaults, and other similar constructions, the offsets are made very narrow, and even these are generally slanted off so as to give the wall or pier what is called a "batter," as represented at A (Fig. 40).

In placing the footings in brick walls, the greatest care must be taken to throw the joints as far back within the surface of the wall as possible. Excepting in walls of one-brick thickness, no course of footings should project more than a quarter-brick beyond the one above it; and additional strength is given by a double course below, which, indeed, should be adopted for every thickness of wall.

Figs. 41 and 42 are sections of walls of different thicknesses.

ANIMAL COMMERCIAL PRODUCTS.—VII.

VII.—HAIR AND BRISTLES.

HAIR, the covering of mammiferous animals, consists of slender, elongated, horny filaments, secreted by a conical gland or bulb, and a capsule, which is situated in the mesh-work of the chorion, or true skin. Bristles, hedgehog spines, and porcupine quills, are all modifications of hair, having the same chemical composition, mode of formation, and general structure. Some kinds of hair are perennial, growing continuously by a persistent activity of the bulb and capsule, as human hair, and that of the mane and tail of the horse; other kinds are annual, the coat being shed at certain seasons of the year, as the ordinary hair of the horse, cow, and deer. Hair, of all animal products, is one the least liable to spontaneous chemical change, and in its various forms is valuable as material for numerous branches of industry.

Human Hair.—This is imported from Germany and France, and is furnished, the light-coloured by the German and the dark-coloured by the French girls, who look forward anxiously to the hair harvest for the means of purchasing trinkets and dresses. A head of hair weighs from eight to twelve ounces, and, according to its colour, is worth from thirty to sixty shillings per pound. In the spring, the Paris hair merchants send agents to all parts of France to purchase the beautiful tresses of the French girls, who cultivate an annual crop for sale with the same care as the farmer cultivates a field crop. About 200,000 lb. are purchased in this way every spring, and made into perukes, false curls, etc. Human hair is also manufactured into a variety of articles of personal adornment known in commerce as hair jewellery, such as bracelets, armlets, lockets, brooches, necklace-rings, watch-rings, which are not unfrequently worn in memory of the person to whom the hair belonged.

Horsehair.—This is collected in the various towns of England from ostlers and others, and sent up to London in sacks. Besides that supplied by our own horses, we import annually from Russia and South America about 20,000 cwt. Horsehair is extensively used for military accoutrements, and as stuffing for mattresses; a cloth of great durability is manufactured from it, and employed in covering sofas, chair bottoms, and railway carriages. The first crinoline petticoats were made from horsehair, and hence the origin of the name (Latin, *crinum*, hair).

The hair of the elk, ox, goat, and camel is also extensively imported into this country, and used for various purposes. The hair pencils used by artists, and termed camel's hair pencils, are composed of the fine hairs furnished by the sable, miniver, marten, badger, and polecat, as well as by the camel. They are usually mounted when small in quills, and when larger in tinned iron tubes. A good hair pencil is known by forming a fine point when moistened and drawn through the lips, all the hairs uniting in its formation.

The quantity of hair imported for the use of our manufacturers in 1886 was—

	Cwt.	Value.
Ox and elk	83,941	£124,643
Horse	19,987	150,209

Bristles are the stiff, glossy hairs growing on the backs of wild and domesticated swine. They are used in the manufacture of brushes for the hair, clothing, teeth, and nails. Russia is the great mart for bristles, those of the Ukraine being most esteemed; France also yields considerable quantities. Bristles are of various colours—black, grey, yellow; but the kind called the lily, on account of its silvery whiteness, is the most valued, and is used chiefly for shaving brushes, tooth brushes, and the softer descriptions of hair brushes. In 1886 British imports from the rest of Europe amounted to 2,063,376 lbs., valued at £296,193; from China (exclusive of Hong Kong), 280,106 lbs., valued at £31,698; from the United States, 79,717 lbs., valued at £5,502; from other foreign countries, 2,597 lbs., valued at £220; from British possessions, 234,713 lbs., valued at £33,626—making a grand total of 2,660,509 lbs., valued at £367,239.

The Porcupine (*Hystrix cristata*, L.).—This animal is found throughout Southern Europe, and allied generic forms exist in North America. The porcupine quills sold in England are chiefly obtained from the European species, which is not common; therefore the quills are expensive. Work-piercers or eyeletteers for ladies, penholders, toothpicks, fish-floats, and fancy workboxes, are made from these quills.

VIII.—HORNS AND ALLIED SUBSTANCES.

I.—HORNS.

In zoology, all hard and more or less elongated processes projecting from the head are called horns. These natural weapons are either solid bone only, when they are called antlers, as in the stag; or they are composed of bone and horn, as in the sheep, goat, and ox. Horns of the latter kind consist of a hollow bony basis or core, on the surface of which is secreted a number of thin layers of true horny material. In the case of the giraffe, the horns consist of bone covered with hair, and are not deciduous. The horn of the rhinoceros is a mere appendage of the skin, and consists of horny fibres or hairs matted together. The antlers of the stag are shed annually, their fall being coincident with the shedding of the hair. True horns, or those which consist either partly or entirely of horny material, are never shed.

Chemically considered, horn may be regarded as intermediate in composition between albumen and gelatine, with a very small per-centage of earthy matter. There is a graduated connection subsisting between the substance of horns, nails, claws, hoofs, feathers, scales, hair, and even skin. The animals that supply horn for our manufactures are principally oxen, bulls and cows, goats and sheep, their horns being preferred on account of superior whiteness and transparency.

The first process in horn manufacture consists in effecting a separation of the true horn from its bony basis. This is accomplished by macerating the horns in water, which causes putrefaction of the membrane lying between the core and the horny sheath, and renders the former easily separable from the latter. The horn then goes through the processes of scalding and roasting, which soften it, and render the laminæ capable of separation from each other. It is next slit with a strong pointed knife; and by the application of a pair of pincers, one to each end of the slit, the cylinder or cone of horn is opened until it is nearly flat. These flats are then placed on their edges, vertically, in a strong iron trough, having between them plates of iron, half an inch thick and eight inches square, which have been previously heated and greased. These plates are now powerfully compressed by means of wedges driven in at the ends, the degree of pressure depending on the use to be made of the horn. For the leaves of lanterns, it must be sufficiently strong to break the grain or cause the laminæ of the horn to separate a little, so as to allow of the introduction of a round pointed knife between them, to complete the separation; for combs, a very slight degree of compression is enough, otherwise the breaking of the grain would cause the teeth of the comb to split at their points. The sheets of horn are next removed from the press and placed, one at a time, on a board covered with bull's hide, secured with a wedge, and scraped with a draw-knife, having a wire edge turned by means of a steel rubber. When reduced to the proper thickness, the horn plates are polished with a woollen rag dipped in charcoal powder, a little water being added from time to time; they are then rubbed with rottenstone, and finished with horn shavings.

When combs are ordered which are too large to be made from a single plate of horn, two or more plates may be united by the skilful application of pressure and of heat, sufficient to melt the horn; and when well managed, the line of union cannot be detected. The Chinese are very skilful in this kind of work, as is evident from their large globular lanterns, some of which are four feet in diameter, and which are made of small united plates of coloured and painted horn. The painted toys known as Chinese sensitive leaves, which the heat of the hand or of a fire will cause to curl up as if alive, are made from the best of the thin films of horn scraped off the plate by the draw-knife.

Horn is easily dyed, as can be seen in the above-named lanterns of the Chinese. In Great Britain it is usually coloured of a rich reddish-brown, and spotted to imitate tortoise-shell. This is effected by boiling together, for half an hour, a mixture of red-lead, pearlash, quicklime, and a little pounded dragon's-blood, and applying the mixture hot to the parts of the horn which it is intended to colour. If a deeper colour be required, a second application of the above mixture must be made; and for a blacker brown, the dragon's-blood is omitted.

AGRICULTURAL DRAINAGE AND IRRIGATION.—IV.

By J. Wrightson, Professor of Agriculture, Royal School of Mines.

VARIOUS METHODS OF DRAINAGE.

The various methods of drainage employed owe their existence to facts duly considered in the last lesson—namely, the different characters of soil with which the drainer has to cope, and the three modes in which land suffers from wetness. First let us glance at the method practised by Mr. Elkington in the latter portion of last century. That Mr. Elkington's method of procedure in draining land attracted general attention is clearly shown by the fact that, as soon as the Board of Agriculture was established, and in consequence of a motion made by its President on the 10th of June, 1795, the House of Commons voted an address, "That His Majesty would be graciously pleased to give directions for issuing to Mr. John Elkington, as an inducement to discover his mode of draining, such sum as His Majesty in his wisdom shall think proper, not exceeding the sum of £1,000 sterling."

As Mr. Elkington's health was at that time failing, the Board resolved to send Mr. John Johnstone on a visit of inspection with the great drainage authority, to report on all that he saw in his tour. Such was the origin of the volume which contains the only account of the work of a remarkable man and a leader in agricultural improvement. A new edition appeared in 1841, from which we gather the following information:—In the year 1763, Mr. Elkington was left by his father a farm called Princethorp, in the parish of Stretton-upon-Dunsmore, in Warwickshire. The soil of this farm being poor and wet, as well as unsound for sheep, he determined to drain it. He commenced with a wet clay field, which was almost a swamp, and in some places a shaking bog, in consequence of springs issuing from an adjacent bank of gravel and sand. In order to drain this field, a trench was cut a little below the upper margin of the bog, about four or five feet deep. This trench ran parallel with the bank of sand just named, and after proceeding with it for some distance in this direction, he found that the main source of the water was evidently not yet reached. While considering what plan to pursue, a labourer happened to come into the field with an iron crowbar, an implement commonly used in

making holes for hurdle-stakes in folding sheep on the land. Mr. Elkington, suspecting that his drain was not deep enough, and wishing to know what kind of stratum lay under it, took the bar and forced it down about four feet below the bottom of the trench. On withdrawing it, to his astonishment a great quantity of water burst up through the hole he had thus made, and ran down the trench. This singular experience was the first of a series of similar trials and successes, which, since they can only be associated with a particular arrangement of the superficial strata, need a few words of explanation. The diagram shown in Fig. 2 represents the section of the field in which this remarkable discovery was made. It will be observed that the upper portion of the sloping ground forming the field is of gravelly and sandy character, and that at some distance beneath the surface is a clay bed, which would offer an obstruction to the downward passage of water. Upon it, then, water will accumulate. It will also be pent in by the clay and peat bed shown in the diagram. The water then rises until it reaches a point over which it can overflow, and this it does in the form of springs along the line which indicates the higher water level. The consequence is that the land on the surface immediately below this outlet of springs is rendered wet and boggy, until in its downward passage the water once more meets a porous rock, through which it disappears, still following the line of clay and leaving the surface dry. This, then, was the state of the field when Mr. Elkington undertook to drain it. The trench shown in the figure was cut parallel with the line of outbursts of springs, but it was not deep enough to reach the real source of wetness. It was at this point that the auger was found useful.

Piercing below the bottom of the trench, the water-bearing stratum was tapped, and the withdrawal of the crowbar was followed by a rush of water, at that depth under considerable pressure. It is clear that the consequence of this liberation would be the lowering of the water-table from the higher level down to the level of the bottom of the drain. The springs would immediately be dried, and the land below rendered sound. This, then, was the principle of Elkington's mode of draining —a method requiring an alternation of porous with tenacious strata, and evidently unfitted for soils wet from direct rainfall. Great sagacity, gained only by experience, and assisted by considerable geological knowledge, is requisite before it can be successfully applied, even in situations where it will be most likely to succeed. These qualities were possessed by Mr. Elkington in a marked degree, insomuch that his power of tracking a spring to its source appeared almost instinctive. It is not our intention to enter minutely into this system of drainage. The case of the field in which the discovery above described was made is a key to the method used by Mr. Elkington in countless other cases. Thus, if we examine carefully the nineteen plates illustrative of these drainage works found in Mr. Johnstone's work we shall find an almost tedious repetition, and occasionally an almost incredible arrangement of strata. All, however, point to the same principle—namely, that where land is wet from the accumulation of water upon a clay, and its rising until it finally bursts out in springs wetting the surface, under such circumstances the land can only be dried by an arrangement of trenches which will attack the source rather than the supply of water. One more case is, however, of interest, and that is where water is afforded an artificial passage through a clay bed into a porous stratum beneath, and thus got rid of. This is a method of drainage which may occasionally be carried out where there is a difficulty in finding a surface outlet. In such a case, if the underlying strata are suitable, a hole may be bored through the retentive material which bears up the water down into the underlying porous rock, which will then be used as an outfall for surface water. Lastly, the auger or boring apparatus must not be looked upon as involving any principle, but merely as saving excavation. In all cases deepening the trench would answer equally well as a means of reaching the water-bearing stratum, but this is done by a boring implement with less expenditure of labour.

The late Mr. Smith, of Deanstone, is credited with having originated the system of drainage usually employed at the present time. His practice was given to the world in 1823, and since then it has been modified by the materials used in constructing the underground channel rather than in any point of arrangement. This system is essentially uniform. Assuming that the source of wetness is co-extensive with the land, the Deanstone method consists in laying down a regular system of underground drains at equal distances apart and of equal depth. As these channels very frequently follow the line of ridge and furrow used in ordinary cultivation, the system has obtained the name of "furrow draining," and because it proposes to thoroughly and uniformly dry the soil, it has been spoken of as "thorough draining." These furrow drains enter a common channel of larger size, which is called the "main drain," and this carries the accumulated water of all the furrow drains to a suitable "outfall." The arrangement of furrow drains, connected at their lower extremities with main drains, has suggested the name of the "gridiron system," and the fact that furrow drains occasionally are made to enter on both sides of a main has conferred the title of "herring-bone" upon this system of drainage. We notice these various designations because they will enable the reader to at once realise, and without any difficulty, the main features of the method of drainage which, from the name of its inventor, is known as the Deanstone system.

At a future time we hope to minutely describe the drainage of a field, and to consider every possible difficulty that may be met with. The following brief sketch must, however, for the present suffice.

A suitable outfall is the first care of the drainer, and this he will make at the lowest point of the system of underground pipes. The next matter to be considered is the main drain, which extends from the outfall and follows the lowest line of ground, either along the foot of a hill or the bottom of a valley. Then we have to fix the position of the furrow drains, following, as a rule, the line of greatest slope, and entering upon one or both sides of the main drain as may be determined by the contour of the ground which it is desired to relieve of surplus water.

Such is the general plan, which hardly requires further illustration. The outfall should be made at a sound point in the bank of some neighbouring open watercourse, where there is no danger of the bank being washed away by the restless stream. Neither should outlets be multiplied, since each may be looked upon as a point of weakness, liable to invasion from animals and injury from accidents. Further, they must be made strong and secure, furnished with an iron mouth extending a few feet in the direction of the drain, fenced with an iron grating, and faced up with mason-work. One outlet ought to suffice for ten acres of land. With regard to main drains, they must be large enough to hold the water sent down to them from the furrow drains. They should also be a few inches deeper than the smaller drains, and this extra depth must be used to secure a rapid fall of the furrow-water into the main drain. Furrow drains, moreover, must not be made to enter the two sides of a main exactly opposite to each other, but alternately.

Again, there occur cases in which the bottom of a valley is flat. Here the fall of the furrow drains will end before they reach the main drain, and the consequence will be a check to the flow of water. A double main drain must in such cases be made. Each recurring furrow drains only on one side. Such an arrangement will secure the drying of the intervening space between the mains, as these will act just in the same way as ordinary drains upon the soil in their immediate vicinity. The chief points to decide with reference to furrow drains are their depth and distance apart, which will be governed in every instance by the character of the soil that is to be drained. As, however, some of the points that we have just brought under notice will receive further elucidation, we shall reserve them for more complete discussion when we consider the details of drainage work.

MATERIALS.

Any material will suffice for the underground channel which is cheap, portable, durable, and, at the same time, fitted for allowing water a free passage. A passage for water is, indeed, all that is requisite, and hence the fact that draining has been and is often practised without the help of any extraneous material, the sides of the channel being formed from the earth itself, just as the rock perforated by a tunnel, or the sand pierced by

a rabbit, forms of itself the wall of the aperture. Among the most evanescent materials which have been used are thorns. Although these, when protected from changes of temperature and from the air, remain in activity longer than we might expect, yet after incurring the expense of digging the trenches it is exceedingly unwise to use them, as they cannot be looked upon as forming permanent channels for water. Captain Walter Blythe recommends "good green faggots, willow, alder, elme, or thorne," which, together with stones, were about the only materials of a lasting character to be had at the time. Mr. Smith of Deanstone, so late as 1823, named stones, broken to such a size as to pass through a three-inch ring, as suitable material for furrow drains, but preferred water-worn or rounded pebbles when they could be obtained easily. The receiving or main drains were to be formed of a culvert of stonework or of tiles. Where there is an abundant supply of stones in the immediate vicinity of the drainage works, it may even at the present day be economical to use them as drainage materials, and if well handled there is no reason why they should not make an efficient channel.

Stones may be built into a square or a three-sided A or V-formed culvert. They may be also broken and placed in the bottom of a trench. In this case a harp or screen is used for separating the large from the smaller stones, the larger being placed at the bottom, and the smaller forming the top of the channel. This arrangement prevents the infiltration of earth and final stopping of the drain, which would be unavoidable if a reverse order of disposition was used. The security of the drain is also further ensured by a layer of straw on the top of the smaller stones, which as it decays will form a protective coat between them and the loose soil above.

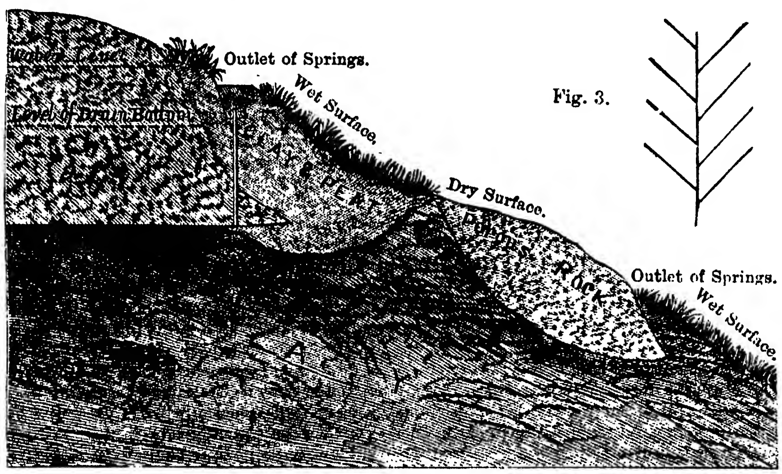


Fig. 3.

Fig. 2.

The draining tile is by far the best material for the purpose, and as it has passed through several modifications of form it will be well to glance at its history. The first efforts to manufacture draining tiles resulted in cumbrous and expensive fabrications, having few if any points to recommend them when contrasted with stone drains. They involved the same wide trench—one of the most fatal failings of stones as a drainage material. The modern pipe allows of the minimum amount of digging in forming the trench, and this is one of its leading advantages.

The horse-shoe—or, as it might with propriety be named, the U-formed—tile appears to have been used as early as 1760 at Crandesburg Hall, in Suffolk, by Mr. Charles Lawrence, the owner of the estate (Gisborne), and these, with slight alterations and improvements in form and material, were used until very recent times. This tile was open to two serious objections. Its horse-shoe form was a cause of weakness, as when the sides of the trench began to be pressed inwards by lateral pressure and the swelling of wet clay, the tile was apt to break longitudinally along the crown. Another source of failure was from the pressing upwards of the bottom of the drain, owing also to the weight of earth on either side. This upward pressure, combined with the wearing action of water in the drain and the gradual settling of the tile, soon caused an interruption of the channel, the tile becoming full of earth. An attempt was made to overcome this failing by forming a round or rather elliptical drain, placing two horse-shoe tiles one above the other, the lowermost one being upside down, and "soles" were also introduced for the purpose of preventing the sinking of the open tile. Still the breakage of the tile from pressure continued, and rendered the work liable to failure. The next improvement consisted in making the tile and sole in one piece, forming a D-shaped tile, and thus the way was prepared for the last important innovation, the round draining pipe. So far back as sixty to seventy years ago, pipes for land drainage were concurrently used by Sir T. Wichcote, of Asgarby, Lincolnshire; Mr. R. Harvey, of Epping; Mr. Boulton, of Great Tew; and Mr. John Read, at Horsemonden, Kent. Mr. Boulton's were one-inch pipes, and it is an interesting fact (which we derive from Mr. Gisborne's valuable essay) that these were made of porcelain by Wedgwood at Etruria, showing that in the same works where exquisite medallions and vases of a character adapted to elevate public taste were being executed, attention was also being given to the development of a less beautiful but equally important manufacture. The general adoption of pipe-tiles did not, however, take place for some years later. In Vol. IV. of the Royal Agricultural Society's Journal for 1843 two excellent papers appeared upon land-drainage, the first by Mr. Thomas Arkell, of Stratton St. Margaret's, Swindon, and the second by Mr. Robert Beart, but in neither of them is any other tile mentioned or figured, but the ordinary horse-shoe tile with soles.

In the same volume is to be found a report by Mr. Josiah Parkes, consulting engineer to the Society, upon drain-tiles and drainage. "The society had offered a premium of ten sovereigns for the drain-tile which should fulfil certain specified conditions, but it was found quite impossible in the show-yard to authenticate the facts required; consequently this prize was not adjudged." A silver medal was awarded by the judges to Mr. John Read, 35, Regent Circus, Piccadilly, for specimens of cylindrical or pipe tiles invented by him. These tiles were from 1 to 2 in. internal diameter, twelve inches in length, and were offered at £1 to £1 14s. and £1 18s. per thousand. "It does not appear," writes Mr. Parkes, "that pipes have been anywhere used for land drains at a period more remote than thirty-five years since, about which time Mr. John Read made and employed them, when servant to the late Rev. Dr. Marriott, of Horsemonden, in Kent. These were about three inches in diameter, and were made by bending a sheet of clay over a wooden cylindrical mandril. This simple form of tile was well adapted for a more rapid mode of manufacture."

It would occupy too much space to enter at any length into particulars regarding the different machines which have been brought out for perfecting the manufacture of tiles. Mr. Pusey relates, in Vol. III. of the Royal Agricultural Society's Journal (1842), how the cost of tiles had been a great check to their employment, and how, about two years previously, while 40s., 50s., and 60s. per thousand were paid for tiles in the south of England, Mr. Beart, of Godmanchester, had five years before invented a simple machine by which he had reduced the price of tiles from 40s. to 22s. throughout Huntingdonshire. The Marquis of Tweeddale followed with a most ingenious machine, and at the Bristol meeting Mr. Irving exhibited an apparatus for the same purpose. Formerly tiles, whether cylindrical or horse-shoe shaped, were perforated with occasional holes to allow water to enter easily. This is, however, quite unnecessary, as water will have no difficulty in penetrating through the porous material of which they are formed, and when we remember the joints which occur between each tile, it is evident that there is enough space for its entrance.

COLOUR.—III.

By Professor A. H. Church, M.A., Royal Academy, London.

PRODUCTION OF COLOUR BY TRANSMISSION, ETC.—MUTUAL RELATION OF COLOURS.

The absorption and reflection of light are very closely related, yet there are many coloured bodies which instead of absorbing some rays and reflecting others, transmit those rays which they do not reflect. Even a third condition exists, in which a substance reflects some rays of the incident light, transmits others, and absorbs the remainder. We may now briefly consider the production of colour by these three methods.

Let us suppose a substance which appears red by reflected light and red also by transmitted light. Of the white light which has fallen upon it and which it has decomposed, it has absorbed or quenched all the colours save the red; while of the red it has transmitted part and reflected part. But the instances in which a substance appears of a very distinct colour owing to reflection are rare. A few metals may be cited as examples along with such substances as murexide, magnesium platinocyanide, potassium permanganate, and indigo. The yellow colour of gold is due to selective reflection. A plate of this metal reflects much of the incident light unchanged, but it quenches in another portion much of the violet and other very refrangible rays, and so leaves the residual red, orange, and yellow rays to produce their colouring effect. It might seem likely that gold would transmit when in sufficiently thin leaves all those coloured rays which it does not reflect. This is true to a great extent; still the grass-green light which a leaf of gold transmits is not perfectly complementary to the orange-yellow which it reflects, some of the constituent rays of the original white light having been absorbed. Solid indigo affords us a similar example of selective absorption and reflection. If a lump of pure indigo be pressed with an agate burnisher, a copper-coloured streak makes its appearance. As long as the substance of the indigo is not coherent—that is, as long as it is in minute powdery particles—so long it shows no symptom of a copper-coloured reflection, but is blue. Now the blueness of powdered indigo thus seen by reflection is not really produced by or in reflection, but rather during transmission of light from particle to particle of the powder. A chromatic selection is thus made, and the light finally reflected to the eye has been deprived of several of its coloured elements. Increase the coherence of the blue indigo powder either by pressure, or by the chemical process of sublimation, by which crystals may be formed, and then, though the transmitted light will remain blue as before, the reflected light will be chiefly copper-coloured, having been deprived by reflection itself of its blue and some other constituent rays. The foregoing facts often suffice to explain the great difference in colour between a solid substance and its powder.

Substances which are commonly regarded as transparent are never perfectly so. For instance, water, flint glass, and rock crystal do not permit all light-rays to travel freely through them. Some substances, such as solutions of the rare metal didymium, and specimens of the mineral known as zircon, absorb or cut off several of the rays of solar light, and yet do not appear perceptibly coloured. The residual transmitted rays in such cases suffice to produce white light. Very thin layers of coloured substances, such as films of tinted liquids, may seem colourless, and yet, when we increase their thickness, colour becomes perceptible. Not only does colour become perceptible, but the colour varies with the thickness. A crystal of blue vitriol shows on its thinnest edges a greenish tint, which alters to a pure blue in the mass. Such a change as this is easily explained. A thin plate of blue vitriol transmits all the blue, a good deal of the green, and a very little of the remaining rays of the spectrum. If we double the thickness of the plate the effect is increased, not in arithmetical but in geometrical proportion. Ultimately, by the extinction of all the rays save the blue, the transmitted light becomes sensibly a homogeneous blue. A very easy mode of observing the striking differences in colour between thin and thick layers was devised by Professor Stokes. A fine slit (one-fiftieth of an inch across) between two blackened metallic edges is adjusted vertically in a blackened piece of board; behind the slit is a source of light, such as a bright flame or the sky. Hold the prism, having an angle of 60°, against the eye; by adjusting the position of the prism a pure spectrum will be obtained, showing, if solar light be used, the principal fixed lines. Now, to observe the absorption of any liquid, fix a test tube or flat cell containing the liquid to be examined behind the slit. Begin the experiment by using a very pale solution, and then gradually increase the strength, noting the gradual appearance of dark lines or spaces in the spectrum and the blotting out of colour after colour. If a wedge-shaped trough be used to hold the coloured liquid behind the slit, it may be gradually moved so as to interpose thicker and thicker layers of the coloured liquids, and thus to produce the same results as those obtained by gradually increasing the strength of the solution. This method is of service when we wish to know the result of diluting any coloured liquid which has to be employed for artistic purposes. Thus, it will be found that some reds, when diluted, instead of becoming pink, pass through orange to yellow; while some blues, instead of becoming paler blues when weakened, become either green on the one hand or violet on the other.

Fig. 4.

Fig. 5.

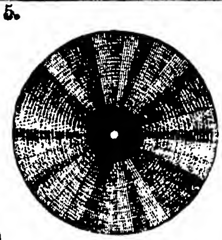


Fig. 6.

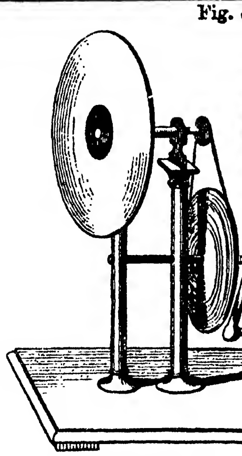


Fig. 7.

We turn now to the re-composition of white light from its constituent elements. There are several ways of accomplishing this result. If we receive the spectrum of coloured rays produced by one prism on another precisely similar prism, but inverted (Fig. 4), the emergent beam, E, will be white. The concentration of a spectrum by a bi-convex lens or a concave mirror gives a white and not a variegated image. Or the seven so-called principal colours of a spectrum may be received upon seven little mirrors (as shown in Fig. 5), and then these mirrors may be so adjusted that their separate images are superposed. In this case also a single white image is obtained.

A less perfect mode of re-uniting colours so as to form white may be accomplished in the manner suggested by Newton. A disc (Fig. 6) is painted in radiating segments with the nearest approach afforded by pigments to the seven colours of the spectrum, the centre and edges being made black. The relative areas of the several colours must be adjusted so as to correspond as far as possible with the normal spectrum, introducing, however, such

differences as the imperfections of the pigments used may demand. As red, green, and blue are the most prominent colours of the spectrum, they should be used in larger proportion than the orange, yellow, indigo, and violet. Indeed, a very respectable kind of whitish grey may be obtained by the use of fewer colours than seven; but of this point we shall have occasion to speak more definitely further on. The best pigments, however, even when used in proper proportions, do not produce a perfect white when the disc painted with them is rapidly revolved (see Fig. 7), so that the retina receives in quick succession the impression of the whole series. All coloured bodies absorb much light and do not reflect really homogeneous rays, and a grey is the result. If several series of similarly coloured segments be painted on the disc the grey more nearly approaches white. In the latter case the eye receives simultaneously the impressions of the several colours, and so the effect does not wholly depend upon the long persistence on the retina of these impressions.

We may now turn our attention to the mutual relations of the several colours.

Reverting for a moment to the pure solar spectrum obtained by means of a prism and a slit, and with the exclusion of all extraneous light, we may first of all notice that it consists mainly of three colours—red, green, and blue. These coloured bands occupy by far the largest area of its most brilliant portion. The orange, yellow, and sea-green, though more brilliant, are very limited in extent, while the indigo and violet region of the spectrum is much less conspicuous. Now for many practical purposes the theory of the existence of only three primary or elementary colours will be found very useful. The selection of these primary colours has, however, been far from unanimous, one set of observers choosing scarlet, green, and blue, another yellow, red, and blue. Nearly all writers on the artistic aspects of colours, such authors as Chevreul, Field, Redgrave and Hay, have accepted the latter selection; but though it undoubtedly affords an easier means of studying the nature of the mixed colours which pigments and paints afford, it is but partially supported by experiments with the pure colours of the spectrum, and in some points is positively contradicted by them. The rival theory, in which the three primaries assumed are scarlet, green, and blue, has been profoundly studied by Maxwell, and has been made the basis of a small treatise on the science of colour by Mr. W. Benson, a London architect, who has done much to further the acceptance of this comparatively modern theory. We shall proceed to give an outline of both views as to the relations of the colours of the spectrum; thus our readers will be able to form their own judgments on the two theories. For our own part we regard Maxwell's experiments as conclusively proving most of the positions he has laid down when pure coloured lights are the subject of comparison and experiment. Yet in actual work with pigments themselves, the older theory affords a more immediate, though often a less exact, answer to any question which may arise.

In order to study the primary or simple, and the secondary or mixed colours, several methods may be pursued. We here name three of the most important of these methods.

Tint two pieces of paper with the two colours to be examined, place the coloured pieces an inch or two apart on a piece of black velvet, and set up, equidistant between them, a slip of thin, colourless plate glass; then adjust the eye so that one coloured patch may be seen by reflection from the near surface of the glass, coincident with the other patch as seen directly through the glass. By inclining the glass the reflected image of one colour may be altered in intensity, and so the relative proportions of the two colours may be varied at pleasure.

Another plan, devised, like the last, by Helmholtz, consists in obtaining two intersecting spectra. Two clean-edged narrow slits, forming together a right angle, thus V, are made in a metallic plate. When this compound slit, brightly illuminated from behind, is viewed by means of a prism about twelve feet off, two overlapping spectra will be seen, the prism being held vertically. As each coloured band of one spectrum crosses all the coloured bands of the other, the result of combining two of the spectrum colours together may be studied. For this purpose it is desirable to employ solar light, the fixed lines of which afford a means of identification of the several colours, and may be readily seen in the above-named spectra by means of a telescope. The telescope is furnished with cross wires, and a diaphragm for limiting the field of view, placed a short distance from the eye-piece of the telescope and close to the eye. A third slit may be used, if it be desired to unite three coloured rays. A modification of this method of producing overlapping spectra consists in cutting out from a piece of white cardboard three pieces of the shape indicated in Fig. 8 by the black spaces. The perforated cardboard, which should be of large size, is placed in a bright light with a piece of black velvet below it. It is then to be viewed six or seven yards off with a prism having its refracting angle turned away from the eye, and placed at right angles with the edge A B of the cardboard figure. No description can give an idea of the beauty of the overlapping spectra thus produced. The results obtained by Helmholtz and Maxwell, by means of experiments conducted by the method of overlapping spectra, will be described below.

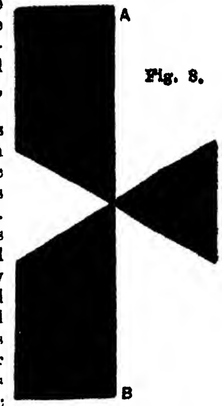


Fig. 8.

A third method of combining colours is by means of a revolving disc such as that represented in Fig. 7. The disc may be painted with the colours it is desired to combine, and then rotated. Of course the proportions of the colours used may be varied not only by painted segments having different areas, but by the superposition of a second or third disc upon the original one, the additional discs having segments of different areas cut out, and being themselves either white, black, or coloured. The various kinds of colour-tops and kaleidoscopic tops may be used for these experiments. We may now give the chief results obtained by Helmholtz and by Maxwell, by means of the first and second methods above described, premising that the statements refer to the coloured rays of the pure spectrum, and not to those of pigments.

Helmholtz concludes that there are five primary colours. These are red, yellow, green, blue, and violet. With these, two or three together, and in various proportions, he obtained nearly perfect representations of the mixed colours. Many combinations of three of them yielded white light. A great range of mixed colours may be obtained by variously combining red, green, and violet. Helmholtz considers these three as affording better results than red, green, and blue, which Maxwell regards as the only essential primary colours, and as infinitely preferable to the older selection of red, yellow, and blue. With regard to the mixture of colours, it appears that the following are among the most important of Helmholtz's results:—

Red + bluish-green = yellow.

$$\left.\begin{array}{l}\text{Red + bluish-green + indigo}\\ \text{Red + greenish-blue}\\ \text{Yellow + indigo}\\ \text{Orange + blue}\end{array}\right\}\ \text{white.}$$

The two most remarkable of these results are the facts that red and bluish-green make yellow, and that yellow must therefore be regarded as a compound colour. When this yellow is united with the deep blue called indigo, it produces white. Here we have two conclusions quite opposed to the result obtained by mixing pigments. When vermilion and emerald green are mixed, a grey with merely a suspicion of yellow is the product. When chrome yellow and indigo are mixed, a distinct green is the product. We have before alluded to the causes of such discrepancies, but may now explain them so far as relates to the examples just cited, since these are typical cases of the kind, and illustrate the two chief points in which the new theory of primary colours differs from the old. Vermilion reflects chiefly red and yellow light to the eye; emerald green chiefly green, but also a little blue and yellow. Mix these coloured powders together, and most of the red, green, and blue they reflect, as long as separately viewed, is either absorbed or re-combined into whiteness, little else remaining but the small quantity of residual yellow rays common to both. Similarly with chrome yellow and indigo; the chief colour they reflect in common is green, and so most of the other rays which they reflect when separate are either quenched when they are mingled, or overpowered by the combined and enhanced effect of the green common to both pigments.

We shall proceed in our next lesson with the account of the new theory of colour by giving some of Maxwell's results.

ELECTRICAL ENGINEERING.—VIII.

BY EDWARD A. O'KEEFFE, B.E., A.S.T.E.,
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PRIMARY BATTERIES.

CLASS I.

CELLS IN WHICH NO ATTEMPT IS MADE TO PREVENT POLARISATION.

THE cell described in Chapter VI. (Figs. 8 and 9) is the typical cell of this section; all the principles there explained (p. 148) apply equally to all those cells which follow, and which are no more than so many ingenious modifications of it, designed for particular purposes.

VOLTA'S PILE.

The first cell that claims attention under this section is Volta's Pile. It was invented by Volta about the year 1799, and is of great historical interest, as being the original form of the primary battery. It consists (Fig. 10) of a series of discs of zinc and copper, separated by discs of flannel which have been dipped in acidulated water, and piled up one upon another in a wooden framework so as to have the appearance of a pillar. The lowest disc is copper; upon this is placed the piece of wet flannel, and upon this a zinc disc. This combination of materials forms a complete cell, similar to that shown in Fig. 8, with the single exception that the vessel containing dilute sulphuric acid has been replaced by flannel moistened with the same liquid. The E.M.F. of this element is of course small, and in order to increase it to any desired amount a considerable number of these discs may be used. Upon the zinc a piece of copper is placed, then wet flannel, then another zinc, and so on; the order—copper, flannel, zinc; copper, flannel, zinc—being adhered to till the pile is as large as is required. Two wires are soldered, one to the lowest copper and one to the uppermost zinc, which form the "poles" of the battery. The copper is the positive, the zinc the negative pole, as is indicated in Fig. 10 by the letters Cu and Zn, which are the symbols for copper and zinc respectively.

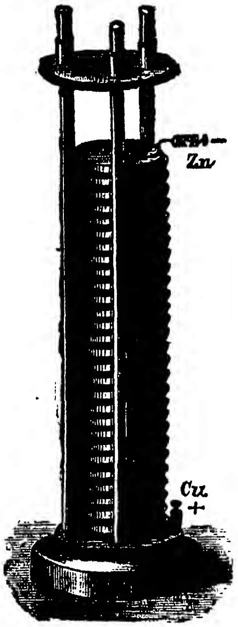


Fig. 10.—VOLTA'S PILE.

This battery or pile has a high E.M.F., owing to the number of separate cells of which it is made up; but it possesses the following serious disadvantages:—

It has an extremely high resistance, and consequently it is impossible to get a strong current from it.

The liquid quickly evaporates, leaving the flannel almost dry, when the pile practically ceases to work.

The liquid from the flannel runs down the surface of the pile, and thus establishes communication between the coppers and zincs outside the separate cells, as was done by the wire in Fig. 8. Small local currents are thus formed which work continuously—even when the pile is not supposed to be in use—and the zinc is thus uselessly consumed.

Bright metallic surfaces should always be in contact with the flannel, which is almost impossible in the pile, owing to the difficulty of taking it to pieces to clean the metals.

PULVERMACHER'S CHAIN.

This is a modification of Volta's pile, and differing from it only in details of construction. It was introduced in 1857, and has been since used in medicine. It consists (Fig. 11), like the pile, of a series of distinct cells, made by winding round pieces of wood spirals of zinc and copper wire carefully *insulated* from one another, and terminating in hooks which enable them to be connected to the corresponding hooks belonging to the metals of the next cell. A large number of these small cells forms the chain. Three of them are shown on a large scale in the lower portion of Fig. 11, from which the method of connection can be clearly seen.

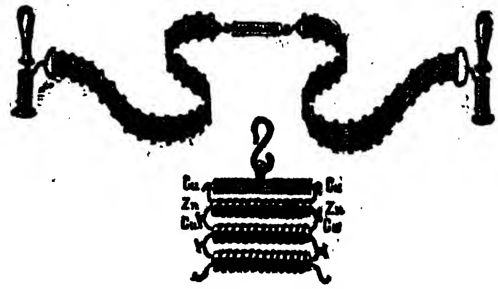


Fig. 11.—PULVERMACHER'S CHAIN.

When it is desired to use this apparatus, it is immersed in vinegar and then withdrawn, the wood absorbing sufficient moisture to supply the aliment necessary for the chemical action.

CRUIKSHANK'S BATTERY.

This consists (Fig. 12) of a long wooden trough divided into a number of separate compartments by rectangular sheets of copper, to which are soldered a like number of rectangular sheets of zinc. The compartments are filled with dilute sulphuric acid, and into the first of them is plunged a sheet of copper to form the positive pole, while a sheet of zinc immersed in the last one forms the negative pole.

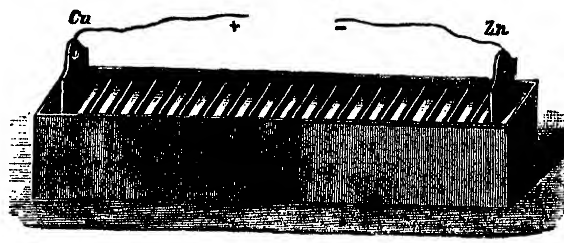


Fig. 12.—CRUIKSHANK'S BATTERY.

This battery has a comparatively low resistance, and can therefore be used to supply fairly strong currents. The sulphate of zinc—which is formed by the chemical action—being heavier than the sulphuric acid, falls to the bottom of the battery, thus allowing the zinc to be attacked by a fresh portion of the acid. There is always a certain amount of local action in this battery, and in order to avoid a useless expenditure of zinc, the liquid should all be poured out of the battery when it is not in use.

WOLLASTON'S BATTERY.

This is somewhat similar to Cruikshank's battery, but possesses some distinctly important improvements. The cells are made of glass or porcelain, and contain dilute sulphuric acid. The metals are zinc and copper arranged in a peculiar manner (Fig. 13). A rectangular zinc plate (Z) dips into the centre of the liquid, and round it is bent a copper plate, the two being kept apart by slips of wood. Connection is made from one cell to another by copper strips (C), which are soldered to the zinc of one cell and to the copper of the next, while the central portion of each strip is firmly attached to the movable framework K. This frame can be raised when the battery is not in use, thus lifting the metals out of the liquid, and avoiding the possibility of any unnecessary waste of materials due to local action, while it saves the labour of re-charging the cells with acid every time the battery is required for use, an operation which has to be gone through when using Cruikshank's battery. The fact of the copper plates being bent as

*

shown, halves the resistance of the battery by increasing the surface of the copper; and this device has since been much used in different types of cells.

This cell polarises very quickly; still, though its E.M.F. is considerably diminished, its resistance is also so low that it can give a fairly strong current. When it has become completely polarised, it can then be relied on to give a perfectly constant current for a considerable time. This property has

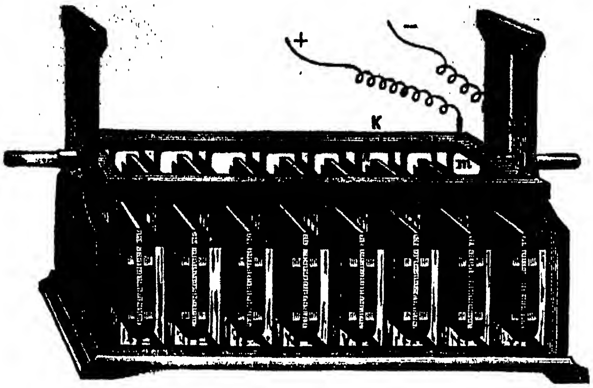


Fig. 13.—WOLLASTON'S BATTERY.

been recognised by those engaged in the electro-plating industry, who often use this battery when it is not desired to deposit the metal too quickly, the battery being allowed to continue working slowly and steadily through the night.

WHICH POLARISATION IS PREVENTED BY MECHANICAL MEANS.

Since polarisation is entirely due to the accumulation of hydrogen bubbles on the negative element, it would seem at first sight as if to get rid of them by some mechanical dodge would be no difficult matter; but experience has proved otherwise. Blowing air through the liquid, keeping the liquid in constant circulation, making the copper plate in the form of a disc mounted on a spindle, which was continuously rotated so as to have half the plate always in the air, while the other half was in the liquid; all these have been tried, but with the same result—they diminished the evil, but failed to get rid of it.

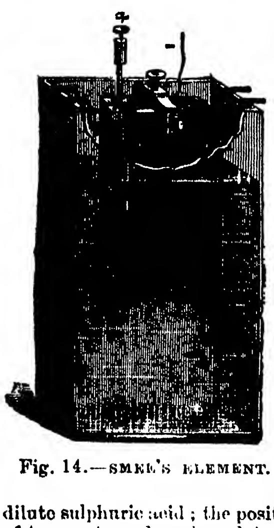


Fig. 14.—SMEE'S ELEMENT.

The best attempt hitherto made to construct a battery in which polarisation is partially eliminated by mechanical means is due to Smee, and his battery is in many respects a distinct advance on any of those described in Class I.

SMEE'S BATTERY.

This battery usually consists of glass vessels containing dilute sulphuric acid; the positive "element," *Zn, Zn*, consisting of two rectangular zinc plates joined together, whilst between them lies the "negative" element, *Ag* (silver), consisting of a rectangular silver plate on which has been deposited a rough coating of platinum. The glass vessel (Fig. 14) is considerably deeper than the plates, so as to allow plenty of space into which the sulphate of zinc can sink.

The chemical action in this cell is similar to that already described, but the ultimate destination of the hydrogen bubbles is different. These bubbles accumulate on the rough platinum points and gradually fall off and rise through the liquid into the air, thus preserving a certain amount of the surface free **from polarisation. By this means the time during which the cell remains in its more active state is prolonged, but, like the others, this cell also ultimately becomes polarised. Fig. 15**

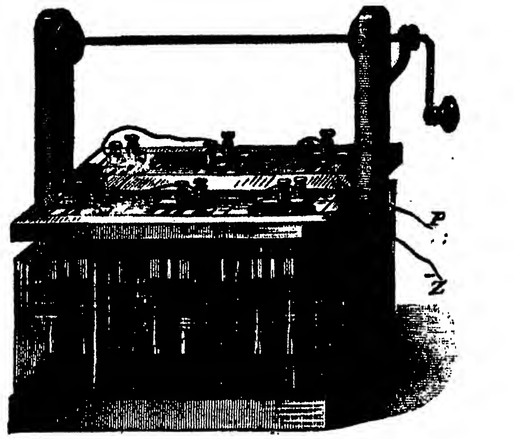


Fig. 15.—SMEE'S BATTERY.

shows how these cells are usually connected up, and the arrangement for lifting them out of the liquid when not actually in use.

This cell is also expensive owing to the negative element being silver, but this silver can be replaced by lead without detriment to the cell.

TELEGRAPH.—III.

By J. M. WIGNER, B.A., B.Sc.

SUBTERRANEAN LINES—SUBMARINE CABLES—FIRST CABLE FROM DOVER TO CALAIS—ATLANTIC CABLES—PERSIAN GULF CABLE—SIEMENS' CABLE.

SUBTERRANEAN lines are but seldom employed except in special and peculiar circumstances, as, for example, in connecting important fortresses or military stations with one another. In case of an invasion all ordinary lines would at once be cut; but if an underground wire has been laid by a circuitous and well-chosen route, it is very difficult to discover it. In the late French war several of these lines, connecting different fortresses, were discovered and cut, but not till after they had rendered good service to the besieged.

Submarine lines are of much greater importance than these, and have demanded in their manufacture all the skill and ingenuity that could be brought to bear. To us, in our snug island home, they are especially important, and by their means we are now linked in electrical circuits with all neighbouring countries as well as with several which are very remote from us.

The first attempt at a submarine cable consisted of a wire coated with gutta percha, which was laid between Dover and Calais in 1850; but this was so imperfect that it failed after the first day. A fresh attempt was, however, made the next year with much increased success. The cable laid on this occasion is represented in Fig. 9, which shows a section of the true size.

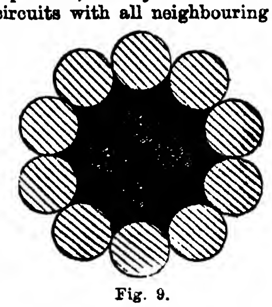


Fig. 9.

The conductor consisted of four copper wires (No. 10 Birmingham wire gauge), each of which was separately insulated by being covered with gutta-percha. These wires were laid side by side, a little hemp being placed between them to prevent their chafing; tarred hemp was then laid on so as to form a solid rope, and outside all, as a protection against accidental injury, there were galvanised iron wires (No. 1 Birmingham wire gauge) spirally wound. The cable, when complete, weighed about seven tons per mile, and possessed very great strength.

It was found to answer admirably, and has remained in working order ever since.

This experiment having succeeded so thoroughly, many other lines were speedily projected and laid, most of which answered well. There have, however, been several failures, and these very costly ones; but they have been the means of drawing attention to defects in the mode of manufacture, so that in the present day success is almost certain, even when the length of the cable is very great.

It will easily be seen that the risk and difficulty increase in a very rapid degree with the length. A few very minute imperfections, so trifling as only to be discovered by the greatest care and scientific skill, will suffice to render a long cable almost useless, and it is very difficult to get at them so as to repair them when once the cable is laid. The pressure of the water, too, at the bottom of the sea is very great, and thus any flaw soon becomes manifest, as the water is forced into it, and makes an escape for the electricity.

The whole of a cable is now constantly and carefully tested during all the processes of its manufacture, so that there is but little chance of a defect passing unobserved. The core after being made is submerged in water, and after remaining so some hours is carefully tested; should any portion prove defective, the exact position of the fault is ascertained, the defective piece is removed, and the core spliced again. The same process is repeated when the cable is complete; and during the process of laying currents are continually transmitted along it, so that faults, should there be any, may at once be detected and removed.

In 1853 a cable was laid between Dover and Ostend; this was very similar in construction to that already figured, but it contained six conducting wires instead of four. More recently this plan has been almost given up, and each cable now usually contains only one conductor, though this is often composed of several wires twisted together.

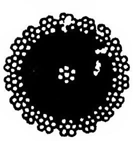


Fig. 10.

In 1856, so rapid had been the advance in the manufacture of telegraph cables that a project was started for making one to connect England and America, and in the summer of 1858 this was completed and laid. The deep-sea portion of this (Fig. 10) was much lighter than those already described, weighing only one ton per mile. The conductor here consisted of seven copper wires, No. 22½ gauge, twisted together. It was considered preferable to employ these instead of a single wire of larger diameter, as in case of any defect in one wire the current would easily be transmitted along the remaining six without being perceptibly interrupted. This strand was carefully covered by three coatings of gutta-percha, so as fully to insulate it; additional protection and strength were then imparted by a serving of jute saturated with tar and other preservative materials, and outside this, eighteen strands of iron wire were carefully wound on, each strand consisting of seven wires No. 22 gauge. Near the shore there is, of course, a much greater risk of accident than in the deep sea, where, when the cable is once laid, it soon becomes covered with sand or silt, and is practically safe from injury. In the shallow water the bottom is more affected by currents and storms, and hence a much stronger portion, known as the shore end, is spliced to the deep-sea part of the cable. In this first Atlantic cable the same core was used as for the deep-sea portion, but instead of the strands of fine iron wire, an extra serving of hemp was laid on, and outside this twelve stout iron wires were coiled, so that the diameter of this portion was nearly three times as great as that of the rest. The total length of the whole was a little over 2,000 miles. It was, however, far from successful; sufficient care was not taken in testing it; hence there were faults in it from the very first, and only a few messages were passed along it before communication entirely ceased. This experiment, being a very costly one, checked a little the manufacture of cables; but the causes of the want of success soon became apparent, and thus much valuable information was obtained even by the failure.

Other cables have since this been laid between England and America, and they have answered well, though some serious difficulties were encountered in laying them.

Faults have occasionally been discovered, but these have been found to arise from injuries inflicted either by design or accident, and have been repaired. In laying one of these, the cable broke and the end was lost. The exact position was, however, noted, and suitable drags being obtained, the end was fished up from the bottom, spliced on to the new cable, and the whole completed. The fact of thus being able to find the end of a cable, lost at a very great depth, is perhaps one of the most wonderful recorded in connection with the laying of submarine cables.

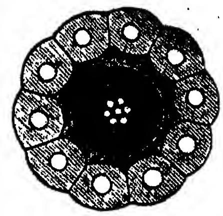


Fig. 11.

The former of these two cables is represented in Fig. 11. The core consists of seven No. 18 gauge wires, twisted into a spiral; this is covered with four coats of gutta-percha, alternating with thin layers of Chatterton's compound, which consists of 3 parts of gutta-percha, 1 of Stockholm tar, and 1 of resin. These bring the diameter of the core nearly up to half an inch. Outside this is a covering of hemp, well saturated with salt water, and an outer layer of ten wires of homogeneous iron. The peculiarity here is that each of these is separately surrounded by Manila yarn, saturated with a preservative compound. For the shore end a portion of the completed deep-sea cable is used, but it is further strengthened by another layer of hemp, and some more wire strands. For submerging this cable the *Great Eastern* steamer was employed, fitted with large tanks, in which the cable was coiled and kept submerged till it was laid. All the core was tested in water at a considerable pressure before it was made up into the cable.

At Bushire, on the Persian Gulf, a number of lines converge. The core of one cable to this port consisted of copper wire of good quality covered with Hooper's india-rubber compound to a diameter of ·320 inch. Two servings of hemp saturated with tar-water were then laid on in reverse directions, and strength was imparted by twelve galvanised wires ·192 inch diameter. These were separately covered with a mixture of tar and asphalte, and the whole then coated externally with two layers of Clark's Patent Asphalte Covering, so as to give it a smooth and even surface.

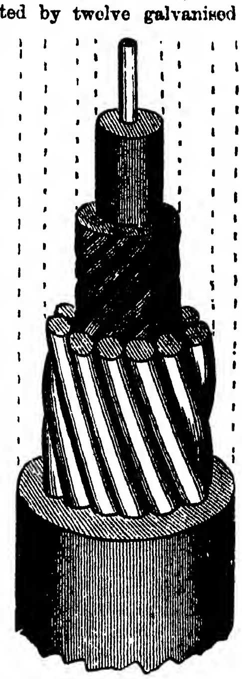


Fig. 12.

Fig. 12 shows a portion of the cable, each layer being separately removed to show the construction, while Fig. 13 shows a section. Many other forms of covering have been tried with varying degrees of success, the object in all being to reduce as far as possible the size, and consequently the weight of the cable. This, however, must not be done at the expense of strength or durability. One cable, constructed by Messrs. Siemens, consisted of a small core, protected in the usual way by fine hemp, and outside this four strips of thin copper sheet were wound round in such a way as partially to overlap one another. This cable, which was laid between Carthagena and Oran, worked uncommonly well for a little time, but it was laid on a very bad bottom, and consequently was soon chafed and broken. When the bed of the sea is rocky the cable is very apt to chafe, especially if there be any great inequalities. The best bottom is a flat one covered with fine sand or silicious deposit. In this a cable is thoroughly protected, and should last almost indefinitely.

We have now carefully inquired into the different ways in which the electric fluid can be conveyed from place to place. It is, however, necessary, as we have seen in our lessons on "Electricity," to have a complete circuit in order that the current may produce an effect; in other words, we must provide some return path for the current, as well as a conductor along which it may travel to its destination. For this purpose a

special wire used to be erected, so that the current might pass along the one and return by the other. This was, however, soon found to be unnecessary, since the earth will answer every purpose of a return wire. All that is requisite is to bury a large plate of metal in the earth near each station, and let the earth wire of the distant station be connected with the one there, while one pole of the battery at the transmitting station is connected with its own earth plate.[1] The current then passes along the wire, through the instrument, on to the earth plate, and back again by the earth plate to the battery, thus completing the circuit.

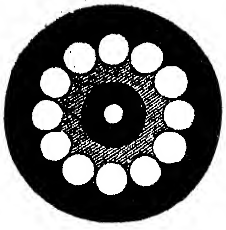


Fig. 13.

There are, however, a few occasions in which a return wire is a great advantage. Strong currents of electricity at times appear to travel from one part of the earth's surface to another. This is especially noticed during the appearance of the Aurora Borealis. Sometimes they continue to flow steadily in one direction, at other times they change very rapidly. These are known as "earth currents," and they seem to enter the wires by one of their earth connections and travel along them, deflecting the needles in their way. If the earth connections be severed, these currents at once cease in the wires; but while they are passing messages are considerably interfered with. Sometimes, when they are steady and uniform, communication may be maintained by cutting the batteries altogether out of circuit, and signalling by the earth current alone. It is not often, however, that this can be done, and the best course then, if there are several wires between the stations, is to alter the connections so as to make one a return wire, joining on the earth wires from the instruments to it instead of to the earth plate. When this is done the whole circuit is completely insulated and cut off from all communication with the earth; the earth currents cannot therefore pass along the wires, and if they affect the working at all, only do so by their inductive action.

Any line of telegraphs—whether aërial, subterranean, or submarine—is liable to injury, as, *e.g.*, by the breaking of an insulator or a wound in the insulating covering, and at first it was a somewhat difficult matter to discover the exact place of the fault, or, as it is termed, to "localise" it, the only plan being to test at intervals all along the line until the exact place at which the communication became defective was discovered. The rapid advance, however, made recently in the construction of delicate pieces of apparatus, and our increased knowledge as to the laws which regulate the passage of electric currents, now enable the operator, without leaving the station at which he is, to discover the exact place of the fault, and thus without loss of time to have it repaired. The manner in which this is accomplished we must explain in our next lesson.

ANIMAL COMMERCIAL PRODUCTS.—VIII.

HORNS AND ALLIED SUBSTANCES (*continued*).

Horn is manufactured into many other articles besides combs. Snuff-boxes, drinking-cups, shoe-horns, and powder-horns are all made of horn. The fragments of horn, melted and compressed into a solid mass in moulds, form bell-pulls, handles for table knives and forks, knobs for drawers, and many other useful articles; or, if exposed to a decomposing heat in close vessels, these fragments develop prussic acid, and for this reason are in demand among the manufacturers of Prussian blue, and of the beautiful yellow prussiate of potash. The solid tips of the horns are always sawn off, because these parts are not lamellated, and therefore incapable of separation into plates. They are made into knife and umbrella handles, the tops of whips, buttons, and various other articles both useful and ornamental.

The quantity of horn annually worked up in the manufactures of Great Britain, including the produce of our own animals, is estimated at 6,400 tons, of the value of £180,000. The comb manufacturers alone consume 1,300 tons, which produce £320,000 worth of combs. Horns of oxen are largely exported from South America, from Buenos Ayres, Monte Video, and Brasil, the last taking, as regards size and quality, the first rank. The Indian buffalo from Siam furnishes a very valuable horn, of which we receive annually about 26,000; the Cape of Good Hope and New South Wales also supply our markets with ox-horns. The manufacture of articles from hoofs and horns is carried on very extensively at Aberdeen in Scotland, where an immense establishment exists.

The hoofs of horses and ruminant animals, though similar to horn in character, are not so useful as horns, because they are much heavier and are less easily worked. They are, however, to some extent made available in the manufacture of buttons, cheap combs, and similar articles.

II. WHALEBONE.

Whale (*Balæna mysticetus*).—This animal furnishes the baleen, or whalebone of commerce. Commonly regarded as a fish, they are nevertheless true mammals, producing their young alive, and suckling them for a considerable time. They are very sociable, swimming in large shoals, and sporting on the surface of the water in their native Arctic seas.

Whalebone or baleen consists of numerous parallel laminæ descending perpendicularly from the palate of the animal. The object of this structure is to form an efficient sieve or strainer for the food of the whale, as it comes in with the water. Although provided with an immense mouth, this enormous creature has an œsophagus or food-pipe so small, that he is compelled to nourish his vast bulk by the consumption of some of the smallest inhabitants of the sea, his food consisting of small mollusca and crustacea. "To procure these insignificant morsels, he engulfs a whole shoal of them at once in his capacious jaws, where they are of course entangled among the fibres of the baleen; the water is then strained off and expelled through the blow-holes, and the monster is thus enabled to pass his diminutive prey at his leisure into his stomach." *

The length of the largest pieces of baleen in a whale sixty feet long is about twelve feet, and the pieces are arranged in two rows, 300 in each. The average weight of each piece is seven pounds, and the weight of the whole is therefore 4,200 pounds, or upwards of one ton and three quarters, worth about £160 a ton.

Whalebone is prepared for use by immersion for twelve hours in boiling water, which softens and renders it fit for manufacturing purposes. It is valued for its flexibility, tenacity, compactness, and lightness, and is cut into quadrangular sticks for the ribs of umbrellas and parasols, the supports of stays and other articles of ladies' wear. In thin strips whalebone is used for covering whip-handles, walking-sticks, and telescopes. These strips also are plaited like straw to form hats and bonnets, whilst the fine shavings are employed by the upholsterers as a stuffing for cushions, for filling fire-grates in summer, and for other useful purposes.

III. OSSEOUS

Antlers.—The antlers of the different species of deer are very valuable for making a variety of useful and ornamental articles. The chief supply is furnished by the elk, wapiti, stag or red deer, and fallow deer. In Switzerland, brooches, pins, and bracelets are made from stag's horn; in Sheffield the whole shaft of the horn is used in making the handles of carving-knives, or it is cut up into small plates and riveted on to an iron case for the handles of pocket and pen knives. About 400 tons are annually imported from Hindostan and Ceylon for this purpose; another 100 tons come from Germany, Russia, Spain, and Italy, and from our own parks. About 18,000 head of deer are annually killed in Greenland, and their horns sent over to this country. The shavings of the horns are employed for the purpose of making ammonia, which has therefore long been popularly known as "hartshorn."

Ivory.—Our supplies of ivory are derived chiefly from the Asiatic and African elephants; the tusks or canine teeth of these animals furnish the article, but those of the African species are the most valuable. Elephants' tusks from two to ten feet in length, and weighing from 6 to 160 pounds, are imported into this country from Senegambia, Guinea, Mozambique, and Sofala; and also brought from the interior of Africa

* W. S. Dallas's "Animal Kingdom." See also Dr. James Murie's paper on the Cetacea, in "Cassell's Natural History," Vol. II.

in caravans and shipped at Alexandria, Tunis, Tripoli, and Cairo. We receive them, besides, from Bengal, Burmah, Siam, Cochin-China, Ceylon, Sumatra, and Java. There are large buildings erected in Birmingham for the manufacture of ivory, and also at Nuremberg in Germany. The Chinese are unrivalled in this manufacture. Their ivory balls, carved one inside another, are marvels of patience, industry, and ingenuity; and their chessmen, cabinets, drinking-cups, and numerous other articles made of this material are most elaborate in their ornamentation.

Generally and technically under the name of ivory are comprised the teeth of the narwhal (*Monodon monoceros*), walrus (*Trichechus rosmarus*), and hippopotamus (*Hippopotamus amphibius*), which, like ivory, are worked up into a variety of things, and always keep white.

Ivory is largely consumed in the manufacture of billiard-balls, which cost from six to twelve shillings each, and are so nicely turned that they are perfectly spherical, and made to correspond accurately in size and weight, even to a single grain. The greatest consumption of ivory is undoubtedly in connection with the cutlery trade. A large amount is also worked up in the manufacture of the backs and handles of the best hair and tooth brushes.

The miniature tablets, so invaluable to the artist, are cut from off the tusk by an extremely thin saw acting horizontally, just as we pare an apple; so that from a solid tusk, of the ordinary size, a sheet of very considerable length can be obtained. In the Great Exhibition of 1851, one manufacturer exhibited a sheet of ivory sixty feet in length, obtained without joining, and which had thus been pared off from a single tusk. In 1886 the British imports of ivory teeth of elephant, sea cow, sea horse, or sea morse, amounted to 9,466 cwts., valued at £448,575. It thus appears that thousands of elephants are killed annually to supply the English market alone.

The material of ivory is so valuable, that economy in its use is necessarily studied, and the smallest fragments are preserved. The refuse of ivory is used for making the finest black colour (*noir d'ivoire*) by converting it into charcoal in air-tight vessels. Such ivory refuse, consisting of ivory scrapings, shavings, and sawdust, when boiled, makes an excellent jelly, quite as good as calf's-foot jelly, and with the advantage that it suffers no change by keeping. Ivory refuse is therefore saleable to the confectioner and pastrycook, by whom it is very frequently employed in this way.

Bone.—The skeleton, or framework of animal bodies consists of bones articulated with each other, which protect the vital organs, and form a basis or support for the softer parts, and for the attachment of the muscles, or organs of locomotion. In the arts, bones are extensively employed by the cutler, comb and brush maker, chemist, confectioner, and agriculturist. Common bone is manufactured into buttons, combs, knife, fork, and brush handles, card cases, parasol handles, book folders, and numerous other articles. The chemist obtains phosphorus, sal-ammoniac, and charcoal from bone, and the farmer a most valuable manure—super-phosphate of lime—which has a quick and efficient action on the crop. Large quantities of bones of oxen are imported to Great Britain from Buenos Ayres, etc., for this purpose; and also the bones of seals, captured in the North Seas for their fur and oil, and brought home by the sealers. The number of tons of bones imported into Britain fo manure in 1886 amounted to 57,282, valued a

TECHNICAL DRAWING.—XII.

DRAWING FOR JOINERS.

The limits of these lessons now render it necessary that some attention should be paid to such examples as form studies for drawing for joiners. Yet we would not wish to be understood that the lessons hitherto given do not appertain to joiners, or that those about to be given possess no value to carpenters. It is difficult to say what is the exact boundary which divides the two branches of wood-work. The general rule, however, is that carpenters' work is structural, and connected with the carcase, whilst that of a joiner comprehends the finishings of the outside and inside of a building. Of course, greater refinement and nicety is required of the joiner in practice; but this will not hurt the carpenter, nor can the structural knowledge required by the carpenter fail to benefit the joiner. In fact, a general knowledge of the practice of each will make both work with greater economy, for one will work into the other's hands; their work will, to use a technical term, "dovetail" together, therefore the two branches are not separated here by a hard line; and that the student may see that the higher branches of joinery approach cabinet-making and wood-carving, examples belonging to both of these branches are introduced. We all know the pleasure it is to meet with a joiner who, in addition to the work of laying down floors, putting up wainscots, or fixing window-sashes, can, when required, set out and execute a piece of Gothic panelling or an organ screen, or who is able to carve any portion of the turn of a moulding which cannot be worked with the plane or struck by the machine. We therefore strongly urge the student to work from the examples herein with the utmost care, and subsequently to follow up the system as he will find it laid down in the special technical lessons devoted to his trade.

Fig. 90 shows the method of uniting the boards *a* and *b* in a flat surface, called "dowelling." The edges of the boards having been accurately planed, holes are bored, pins (as at *e*) are glued into the one, and the projecting ends being inserted into corresponding holes in the edge of the other board, unite them firmly—the edge of the board *c* and the end of the pin being glued.

Square pieces of hard wood, or dowels, are often used in the place of pins, and are shown at *d*.

Fig. 91 is a method frequently adopted in floor-boards and panelling. It is called *rebating*, and consists in planing away half the thickness of the edge, so as to leave a ledge standing; all the boards being thus rebated, the ledge left on the one fills up the rebate, or "abated" edge of the other. This will be clearly understood on referring to the illustration.

Fig. 92 is a method of joining boards called "ploughed and tongued." In this case a groove is planed in the one edge, and a tongue left (by planing away the angles) at the other edge of each board; the tongue of the one then fits into the groove of the other. In very good work it is usual to plough *both* edges, and *insert* a separate tongue. This tongue is formed of strips cut the cross way of the wood, as shown in Fig. 93.

Fig. 94.—This method consists in working grooves across the back of the pieces, *a*, and forcing rabbets into them, as *b b*. The bottom of this groove is flat (A), and its sides slant inwards towards the bottom. The sides of the rabbet are also cut slantingly, and a joint is thus formed called the "dovetail notch."

This method is exceedingly well adapted for making drawing-boards. The rabbets must not then be glued, or otherwise fastened in, and thus, by means of their dovetailed edges, they keep the board from warping, whilst at the same time they allow of its expansion and contraction, and thus splitting and twisting are prevented.

Fig. 95 is an illustration of the method of clamping the ends of boards, *a b*, by tongueing the board and ploughing the piece which is to cross it, *c*. Sometimes, instead of bringing the end of the cross-piece flush with the edge of the board, it is cut off at an angle, the board being cut correspondingly to admit of the insertion. This last method is called *mitre*

Fig. 96 shows a very common method of joining up a flat surface by means of framing and panelling. A groove is run in the edge of the frame, the edges of the panel are rebated, and the whole brought up flush.

Fig. 97 shows a portion of a panel inserted into a frame where a flush surface is not required.

Fig. 98 represents one of the many methods employed for angle joints. It is the simple mortise and tenon, a shoulder being left on the outer side of the tenon by which the one piece is secured against being forced out of perpendicular.

Fig. 99 is another method, which is accomplished by means of a mitre, part of the wood being left as a tenon at the end of the one part, which is inserted into the mortise at the end of the other. A pin is then passed through the whole.

DOORS.

The most common kinds of doors are constructed of several simple boards, not fixed with glue or any tenacious substance, but by nailing transverse pieces upon the back of the boards

laid edge to edge. The transverse pieces thus nailed are called *ledges* or bars, whence the door is said to be ledged or barred. In this case one of the edges at every joint is beaded on both sides, or at least on the face which is outside, the edges being placed on the inside.

Doors of this description are generally employed in cottages or out-houses.

Where doors are required to combine strength, beauty, and durability, a frame, joined with mortise and tenon, must be constructed, with one or more intermediate openings, each of which must be surrounded by three or more parts of the frame, which have grooves ploughed in the edges for the reception of boards to close the openings, inserted as in Fig. 97.

The parts of the framing which are horizontal when the door is hung or fixed upon its hinges are called *rails*—upper, middle, and lower. The extreme parts of the frame, to which the rails are fixed, are called the *stiles*, and the intermediate ones are termed *mountings*. The boards by which the interstices are closed are called *panels*.

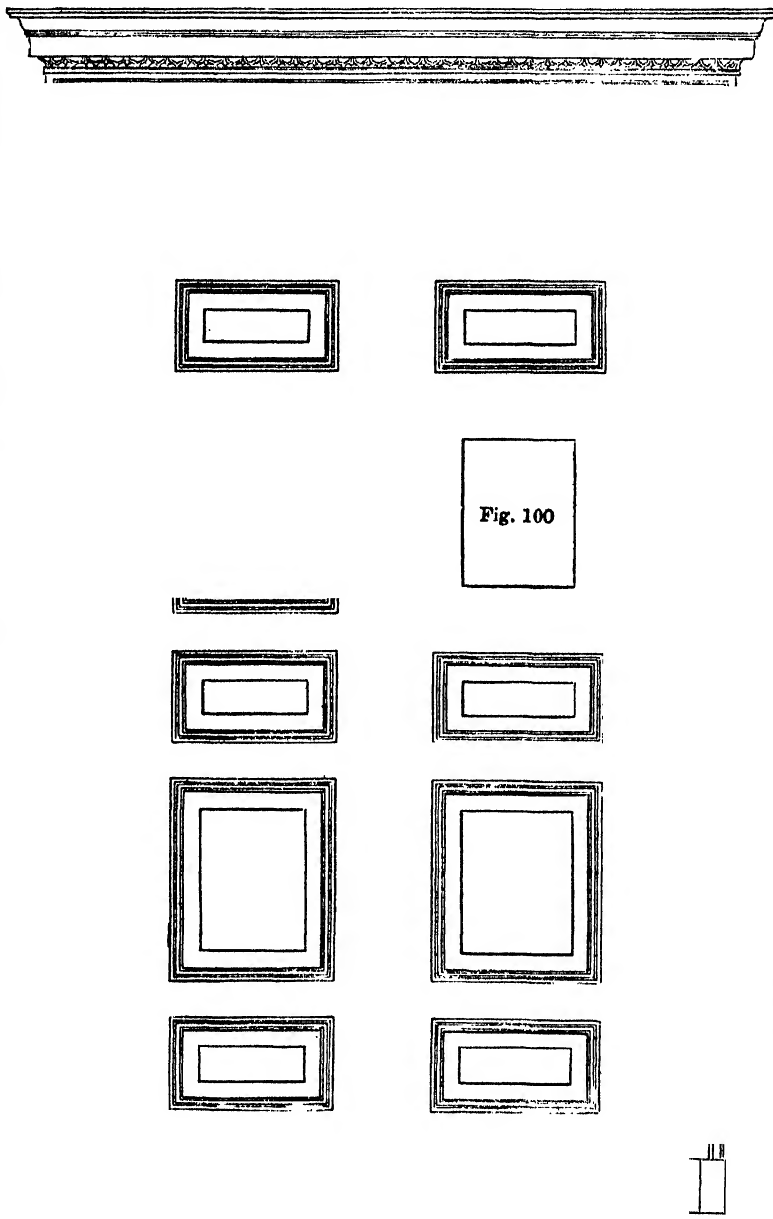


Fig. 100

Fig. 100 is the elevation of a pair of folding-doors, with mouldings and cornice. In this example it is desirable to commence by drawing the entire framing and cornice, with their mouldings. Then draw a central perpendicular, on which mark off the heights of the various rails and panels, and draw horizontal lines for the upper and lower edges of these. From the central perpendicular next set off the width of the stiles, etc., and draw the necessary perpendiculars. The mouldings to the panels may now be added.

Fig. 101 is the section, on a larger scale, of the frieze and cornice, showing how the various members are put together. The ornamental moulding, *f*, is in this design supposed to be made of pressed zinc, in which some very beautiful patterns are now worked, which are by far more durable than those made of composition.

Fig. 102 shows the manner in which such doors meet in the middle.

Fig. 103 is the plan of a folding (or French) window and shutter-box. *a* is the framing of the window; *b*, the window; *c d*, the folding shutter closed; *c d*, ditto folded; *e f i*, the casing of the shutter-box; *g*, the wall; *h*, the inner casing.

PARQUET WORK.

Parquetry is a beautiful species of flooring, consisting of various patterns formed of different woods such as cherry, oak, ebony, walnut, mahogany, maple, etc. It is very much used both in Germany and France, and is now becoming fashionable in England. The wood of which the parquetry consists is usually one inch thick, grooved, tongued, and keyed at the back and corners. It is well adapted for reception rooms and picture galleries, for borders round Turkey carpets, as well as for landings and panelling of rooms.

Fig. 104 is a design based on the square only, and is too simple to require any instructions as to drawing, further than the advice already so frequently given — to work with the utmost accuracy, for in such repeating patterns, any one of the component figures, being inaccurately formed, throws out the whole design.

Fig. 105. — This design is drawn by setting out a number of squares. Draw diagonals and circles from the angles. All the other lines employed will be found to be parallel to these.

Fig. 106 is also based on the square. Having set out a number of squares, divide the sides of each into three equal parts, and draw lines across so as to divide each of the squares into nine smaller ones. In each of the four small squares occupying the corners of the larger ones, draw one diagonal; and in each of the four squares occupying the middle of the sides draw two diagonals. By shading the portions as in the example, the design will be developed.

Fig. 107 is based upon the hexagon. To draw this pattern, construct a line of regular hexagons, each touching two others by their angles; divide each hexagon into six equilateral triangles by diagonals. Find the middle of the sides, and draw lines to the middle points of the alternate sides; these will give two equilateral triangles crossing each other; and the required portions being coloured, the star in the centre will be left. The darker lines are drawn parallel to the sides of the hexagon.

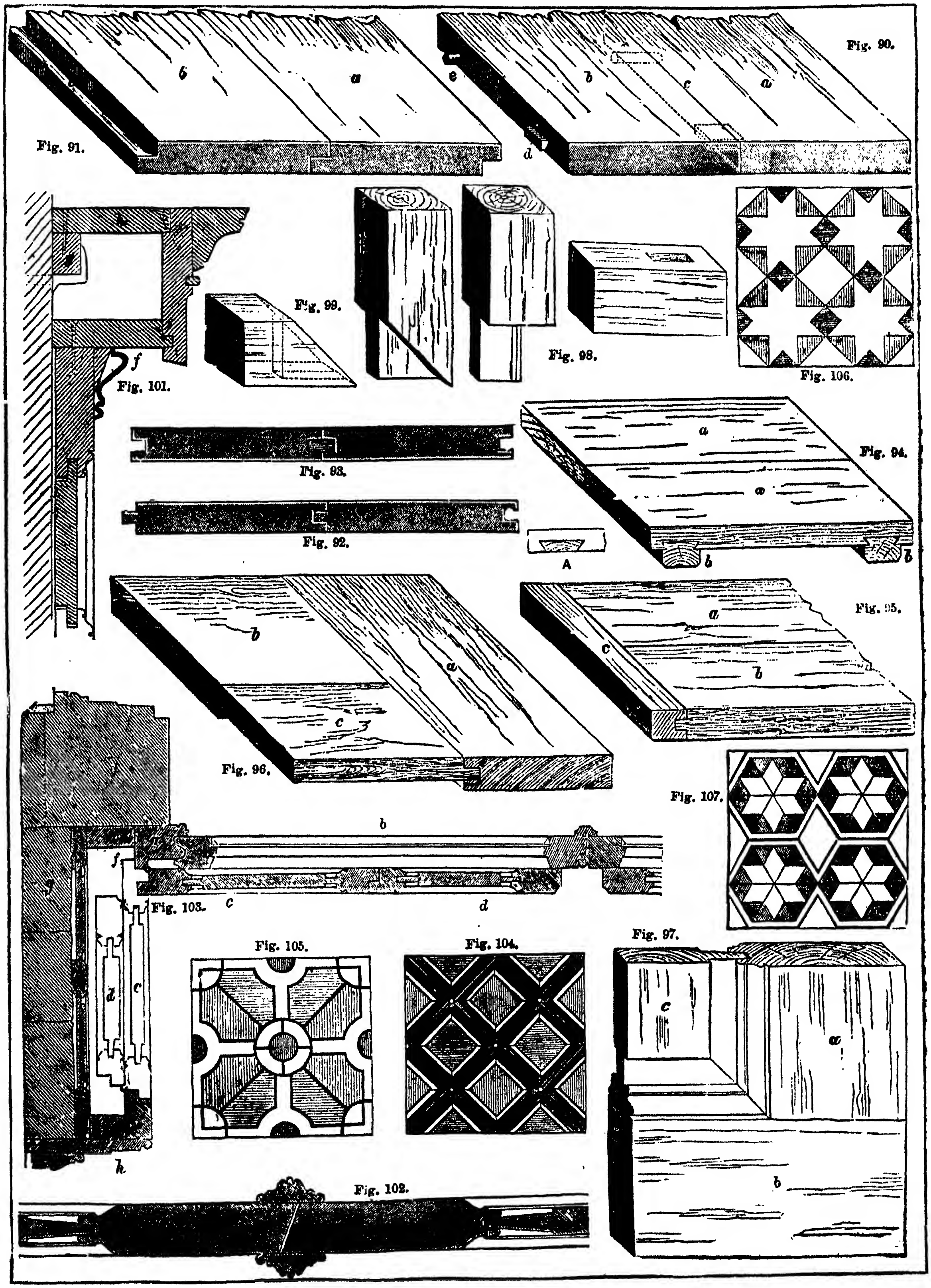


Fig. 90.
Fig. 91.
Fig. 92.
Fig. 93.
Fig. 94.
Fig. 95.
Fig. 96.
Fig. 97.
Fig. 98.
Fig. 99.
Fig. 101.
Fig. 102.
Fig. 103.
Fig. 104.
Fig. 105.
Fig. 106.
Fig. 107.

VEGETABLE COMMERCIAL PRODUCTS.—VI.

PLANTS USED IN THE PREPARATION OF NUTRITIOUS AND STIMULATING BEVERAGES (*continued*).

PARAGUAY TEA, OR MATÉ (*Ilex paraguayensis;* natural order, *Aquifoliaceæ*).—A small shrub with oval, wedge-form, or oblong-lanceolate, toothed, smooth leaves, somewhat like those of the orange. This plant, which is, in fact, a species of holly, occupies the same important position in the domestic economy of South America that the Chinese plant does in this country. The leaves are prepared by drying and roasting—not in the manner of the Chinese teas, in which each leaf is gathered separately; but small branches with the leaves attached to them are cut from the plant, placed on hurdles over a wood fire, roasted, and then beaten on a hard floor with sticks. The dried leaves and stems thus knocked off are collected, reduced to powder, and packed in hide sacks. Each of these sacks, when full, contains from 200 to 250 pounds of the tea. The sacks are sewed up, and as the hide dries and tightens by exposure to the sun over its contents, at the end of a couple of days the tea forms a substance as hard as stone, and almost as heavy.

As found in commerce, Paraguay tea is, therefore, in the form of a greenish-yellow powder, mixed with broken leaves and stems. This is infused in boiling water, and the decoction is drunk, or rather sucked up, by means of a tube perforated with small holes. It is usually imbibed out of a small gourd or cup with a little sugar, and sometimes an aromatic is added, such as orange or lemon-peel, or cinnamon, to give it an additional flavour. Maté is generally disagreeable to those unaccustomed to its use, but a taste for it is soon acquired, and it is very refreshing and acts as a restorative to the human frame after great fatigue.

It has been calculated that 40,000,000 pounds of Paraguay tea are annually consumed in the various South American Republics.

COFFEE TREE (*Coffea arabica*, L.; natural order, *Rubiaceæ;* sub-order, *Cinchonaceæ*).—An evergreen shrub, from fifteen to twenty feet in height, with an erect stem covered with a brownish bark, and opposite branches with a slightly downward inclination, giving to the whole shrub an elegantly beautiful pyramidal contour or outline. Leaves opposite, short-stalked, ovato-lanceolate, entire, glossy dark-green above, paler beneath, and from two to three inches long; flowers, white and funnel-shaped; fruit, a globular two-celled and two-seeded berry, about the size of a cherry. The seeds, freed from their hard, horny, parchment-like husk, are hemispherical, with one side convex, and the other flat and furrowed.

The flowers of the coffee-tree resemble those of the white jessamine, and appear in clusters in the axils of the leaves. The trees are very beautiful and fragrant when in bloom, and not less attractive when the berries are ripe and ready for cropping, for these are then of a deep scarlet colour, and show to great advantage amongst the dark-green glossy leaves.

The home of the coffee-tree is said to be Abyssinia, where it still grows wild; thence it was transplanted to Arabia towards the close of the fifteenth century. It was introduced by the Dutch into Batavia in 1690, and thence carried to the West Indies in the beginning of the eighteenth century, and afterwards to the Brazils. Coffee is now grown in almost every tropical country having an average temperature of above 55°. We receive it from Java in the East Indies, from Trinidad in the West Indies, and from Rio Janeiro in South America. The best coffee comes from Mocha in Yemen, the southernmost province of Arabia.

As soon as the crimson colour of the coffee berry indicates the time for harvesting, the berries, which drop readily when mature, are shaken from the trees upon cloths or mats spread under them. They are then piled together in heaps for forty-eight hours to soften the pulp, and afterwards put into tanks through which water flows continually, to wash off the pulp; the berries are then spread out on the platform, with which every coffee estate is furnished, to dry in the sun. But there still exists the husk, which is broken off by means of heavy rollers; the seeds are then winnowed, and put into bags for sale.

Raw coffee is roasted, after it arrives in this country, in a hollow iron cylinder, which is kept turning for half an hour over a charcoal fire until the berries are coloured sufficiently brown. Roasting coffee improves its flavour and power as a stimulant.

Coffee owes its properties to a peculiar principle, which has been called by chemists caffeine, and which is identical both with the theine of the tea and the theobromine of the cocoa plant. It is worthy of note that the common beverages of man—tea, coffee, and cocoa—although found in the most dissimilar plants, nevertheless contain identically the same peculiar principle which gives them their nutritious and stimulating properties.

Coffee is said to have been first used by the Persians as a beverage as early as 875 A.D., and from them the Arabs learned its value. The first Arab who drank coffee was Megalledin, Mufti of Aden, in Arabia Felix, who had become acquainted with this use of the coffee berry when in Persia. The consumption of coffee was not at all rapid at first, and it was not until 1554 that it was publicly sold at Constantinople. It afterwards became very popular with the Turks, but as it frequently led to social and festive meetings, which were considered incompatible with the strictness of Mahometan discipline, its use was restricted by the Turkish Government, though without effect. In vain the Turkish priests complained to the authorities that the mosques were deserted, whilst the coffee-houses were crowded; in vain the latter were shut up by order of the Mufti, and the police employed to prevent any one from drinking coffee; the Turks found means to elude their vigilance. They would have their coffee. The law, therefore, became only a dead letter, and although never repealed, the Government acknowledged its defeat by finally laying a tax on the beverage, thus making it a source of considerable revenue.

The consumption of coffee in Turkey is very great. This is probably owing to the strict prohibition which the Moslem religion lays against wine and spirituous liquors. So necessary is coffee to the Turks, that the refusal of it in reasonable quantities to a wife is considered to be a sufficient ground for a divorce. The coffee-houses in Turkey are very numerous, and some of them spacious and handsome. In Constantinople, such as are regularly licensed are gaudily painted, and furnished with mats, platforms, and benches. Sometimes there is a fountain in the middle of the room, which renders the atmosphere delightfully cool; and also a gallery for the musicians. Towards evening these houses become thronged with a motley assemblage of Armenians, Greeks, and Jews, all smoking and indulging in tiny cups of coffee, generally drunk without either sugar or milk.

It is in the Turkish coffee-houses that the vagrant story-teller finds his stage and his audience. He walks to and fro, stopping when the sense of his story requires some emphatic expression or attitude, and generally contrives to break off in the most interesting part of his tale, making his escape from the room despite every precaution that may be taken to prevent him. His auditors thus compelled to restrain their curiosity, are induced to return at the same hour to the coffee-room. As soon as he has made his exit, the company present commence an animated discussion, in separate parties, as to the character of the drama, and the principal events of the story.

The following account, by Mr. M'Farlane, is characteristic of Turkish manners, and of the mode in Turkey of setting aside the laws in reference to coffee:—

"I was surprised to see in Smyrna, and in numerous other towns, the scarcity of coffee-houses and the quantity of barbers' shops. It was explained when, on wishing to rest a while, my servant David led me into one of them, which in appearance was devoted to shaving, but which concealed behind a wooden screen, that looked like the end of a room, a spacious recess hung with *chibouks*, or common pipes, *narghiles*, or water pipes, and tiny coffee-cups. The small characteristic fire for the preparation of the fragrant berry was burning in the usual corner, and there were the usual supplies of benches and stools—in short, it was a *bonâ fide* coffee-house, screened by a barber's shop, and a group of Osmanlis shuffled in after us, not to be shaved, but to smoke their pipes and drink their cup of coffee.

"'David,' said I, 'are all these hundreds of barbers' shops nothing but veils for coffee-houses?'

"'Not all, but the greater part of them,' was the answer.

"'Yet the disguise may be easily penetrated. Any bostangi might discover the recess, and arrest a crowd of delinquents, as here, for example.'

"'That is all very true,' said David, 'but what would the bostangi get by that? The fact is, the Turks cannot live

without coffee-houses; besides, the order to shut them up is now an old affair. Each proprietor may make it worth his while not to see, and so you understand the bostangi and his officers need not look beyond the barber's shop.'

"During the latter part of this speech, a Mollah, a stout advocate of both law and gospel, stepped in, and called for his narghile and coffee!"

Coffee was first sold in London in 1652, by a Turkish merchant, who kept a house for that purpose in George Yard, Lombard Street. It soon became very popular, and in 1660 a tax of fourpence on the gallon was levied on all coffee made and sold. It spread amongst the English for reasons very similar to those which caused its spread among the Turks. According to Macaulay,* it extended most rapidly. To be able to spend the evening sociably at a small charge soon become fashionable. The coffee-house was "the Londoner's home." Nobody was excluded who laid down his penny at the bar. There were coffee-houses where politics were discussed, where literary men held their meetings, and where doctors, divines, and lawyers congregated, and might be consulted. "There were Puritan coffee-houses, where no oaths were ever heard, and where lank-haired men discussed election and reprobation through their noses; Popish coffee-houses, where good Protestants believed over their cups that the Jesuits were planning another Gunpowder Plot, and casting silver bullets, to shoot the king; and Jew coffee-houses, where the money-changers of different nations greeted each other." Such was the respectable position of a London coffee-house in 1685. Lloyd's was originally a coffee-house at which insurers and underwriters met. These houses have long ceased to be the favourite haunts of literary men and fashion, and, although still retaining their ancient name, they are now on a level with an ordinary restaurant, having been superseded as places of entertainment by the numerous music-halls and club-rooms in the metropolis, where something more stimulating than coffee is usually in demand.

Coffee, like tea, is frequently adulterated. Of these adulterations the most common one is chicory (*Cichorium intybus*, L.), a plant resembling a dandelion, with blue flowers, belonging to the natural order *Compositæ*. The large tap-roots of this plant are sliced and dried in kilns; they are then roasted and reduced to powder, and this, when boiled, yields a drink not unlike coffee. Chicory is perfectly wholesome, containing no alkaloid or oil, and only a small amount of narcotic matter. When added to coffee in small quantities, it rather improves its flavour, neutralises its oil, and renders it less difficult of digestion. The sale of chicory is now legalised. Many persons prefer the coffee with chicory.

The adulteration of coffee with chicory is easily detected. Roasted coffee imparts its colour very slightly to cold water, but chicory colours the water a deep-reddish brown. Coffee is light, and floats on the surface of the water; chicory is heavy, and sinks to the bottom.

The best coffee, called Mocha coffee, comes from Yemen in Southern Arabia; Loheia and Mocha are the principal ports for its exportation on the Red Sea, besides which, Aden, acquired by England in 1838, will soon become an important coffee mart. About 4,000 tons of this coffee are annually exported. East Indian coffee ranks next in commerce, chiefly the coffees of Ceylon and Batavia. About 50,000 tons of East Indian coffee are annually produced. An inferior kind, called green coffee, is raised in the West Indies—in Jamaica, Cuba, St. Domingo, Trinidad, Guadaloupe, Porto-Rico, and Martinique—to an annual amount of about 70,000 tons. Other American coffees also come from the free States of Venezuela and New Granada, from the Brazils, Cayenne, and Surinam. The annual produce of coffee in South America may be estimated at 81,000 tons. In 1886 there were imported into the United Kingdom 1,006,543 cwts. of coffee, valued at £3,295,028. We export coffee also largely to our colonies and Australia. Hamburg and Amsterdam are the most important coffee markets, and next to these London, Rotterdam, Antwerp, Havre, and Trieste.

COCOA (*Theobroma cacao*, L.; natural order, *Byttneriaceæ*). —A tree, about twenty feet in height, with dark-green leaves, from four to six inches in length and about three inches in breadth, elliptical, oblong, and pointed, the margin entire, and slightly wavy; the flowers are small and white, growing directly both from the stem and branches; the fruit somewhat resembles a cucumber; it is about five inches in length, and three inches and a half in diameter, at first green, but when ripe, yellow. Within this fruit, embedded in the pulp, are from forty to fifty cocoa-beans or seeds, packed closely together in five rows, around a common centre.

The cocoa-trees will grow well only in the shade. They are planted at intervals of twelve feet apart, and are protected from the fierce heat of the tropical sun by the broad-leaved banana and the stately and beautiful *Erythrina*, or coral-tree. The rays of the sun cannot penetrate the foliage of these trees, and the ground below them is constantly wet. When the fruit is ripe, it is plucked and opened; and the beans, cleared of the spongy pulp, are spread upon mats to dry in the sun.

Chocolate and cocoa are both made from these beans. Chocolate is made by first freeing the beans from their husk, and then roasting them over a fire in an iron cylinder, with holes in its end for the escape of the vapour. The apparatus is very similar to that of a coffee-roaster. When the aroma is well developed, the beans are roasted; they are then turned out of the cylinder, and ground to a powder, which, mixed with sugar, flavoured with vanilla, and brought to a paste, forms the chocolate cakes of commerce. Cocoa is prepared by grinding up the entire nut—both husk and kernel—after roasting, a quantity of suet being added during the process of grinding. Sometimes the beans are roasted and simply crushed. preparation is sold in the shops under the name of *cocoa nibs*.

The cocoa-tree is a native of South America, Mexico, and the West Indies, where it formerly grew wild, but is now cultivated in extensive plantations. The beans of this tree have always been the chief means of nourishment of the natives of those countries. From them the Spaniards learnt to make both chocolate and cocoa.

The cocoa bean, which is about the size and colour of an almond, contains a peculiar solid oil called *butter of cocoa*, and an alkaloid called *theobromine*, which produces on the nervous system analogous effects to those of *caffeine* and *theine*. Chocolate and cocoa yield highly nutritious beverages. Linnæus was so convinced of this, that he called the plant *Theobroma*.

Cocoa is imported into this country chiefly in the raw state, that is, the beans with the husks on. The following are the principal sorts which are brought into Europe. The preparation, Chocolat Menier, is from cacao grown in the district of Rivas, Nicaragua. Soconusco, the best sort, comes from the district of the same name in the free state of Guatemala. This seldom comes into the market. Caracas, the next in quality, comes from La Guayra, the commercial port of Caracas in Venezuela, also from Guayaquil in Ecuador. Our largest supplies come from these ports. We receive also heavy shipments from English, Dutch, and French Guiana, Brazil, Mexico, and the West Indies, especially from the island of Trinidad.

In 1886, 25,363,443 lbs. of cocoa were imported into the United Kingdom. Its consumption in France, Spain, and Portugal is continually increasing. Chocolate is more used in France and Spain than in England. It forms the ordinary breakfast of the Mexicans.

Both chocolate and cocoa are much adulterated with wheaten and potato flour.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—III.

IT is now intended to show the construction of Gothic tracery. Some of the figures used in the designs of windows, etc., in churches of the Middle Ages are extremely beautiful; yet all the forms grow out of others of the most simple character, dependent on correct geometrical construction. The quatrefoil, which forms the subject of the present lesson, is based upon a square drawn on given diagonals; and this elementary figure, and one of a similar character, are therefore given as steps in the construction.

To construct a square on a given diagonal, A B (Fig. 24).

Bisect the diagonal A B in the point C. From C, with radius C A, describe a circle cutting the bisecting line in D and E. Draw A D, D B, B E, E A, which will complete the square on the given diagonal A B.

To construct a parallelogram when the diagonal A B *and the length of one pair of sides* C *are given* (Fig. 25).

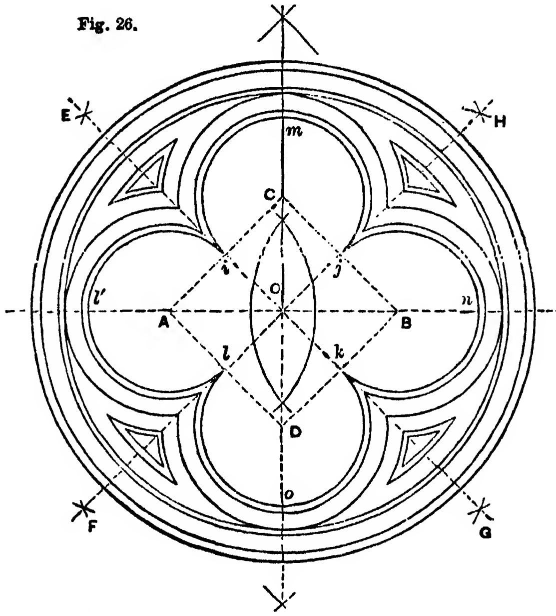
* "History of England, from the Accession of James II.," by Lord Macaulay, Vol. I., p. 175.—People's Edition, 1864.

Bisect A B in the point O. From O, with radius O A, describe a circle. From A and B set off the length of the line C on the circle—viz., A D and B E. Join these points, and the required figure will be completed.

*To construct a Gothic quatrefoil** (Fig. 26).

Construct a square on the diagonal A B (see Fig. 24). Bisect the sides by the lines E G, F H, cutting the lines A C, C B, B D, and D A, in *i*, *j*, *k*, *l*. From A, C, B, and D, with radius A *i*—that is, half the side of the square—draw the arcs *l'*, *m*, *n*, *o*, and those concentric with them. The outer circles are drawn from the centre O.

Fig. 26.



To inscribe a square in any triangle, A B C (Fig. 27).

From C drop a perpendicular, C D. From C draw a line parallel to A B—viz., C E. From C, with radius C D, describe a quadrant cutting C E in F. Draw F A, cutting C B in G. From G draw G H parallel to A B. And from G and H draw lines G I and H J parallel to C D, which will complete the square in the triangle.

To inscribe a square in a given trapezium, A B C D (Fig. 28).

Draw the diagonals A C and B D. Draw D E at right angles and equal to D B. Draw E A, cutting C D in F. Draw F G parallel to A C. Draw G H and F I parallel to D B. Join H I, which will complete the square in the trapezium.

To inscribe a circle in a given trapezium, A B C D, *of which the adjacent sides are equal* (Fig. 29).

To trisect† a right angle, A B C (Fig. 30).

From B, with any radius, describe the quadrant D E. From D, with the radius D B, describe an arc cutting E D in F. From E, with the same radius, describe an arc cutting E D in G. Draw lines B F and B G, which will trisect right angle.

THE MEASUREMENT OF ANGLES (Fig. 31).

Angles are estimated according to the position which the two lines of which they are formed occupy as radii of a circle.

The circle being divided into 360 equal parts, called "degrees," it will be evident that the lines A O C contain 90 degrees (written 90°), or a right angle. Similarly, B O C is a right angle.

Now, if these right angles be trisected (as per last problem), each of the divisions will contain 30°, thus:—

A O E	is an angle of		30°
A O F	"	"	60°
A O C	"	"	90°
A O G	"	"	120°
A O H	"	"	150°

A O B is in reality not any angle at all, being a perfectly straight line; but the slightest divergence from it would cause it to become an angle; as 179°, etc.

Each of these angles being again divided into three parts will give tens, which may again be divided into units; and thus angles may be constructed or measured with the greatest accuracy.

Fig. 24.

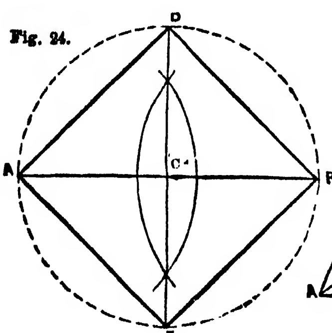


Fig. 27.

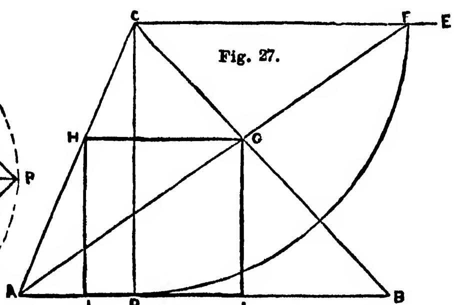
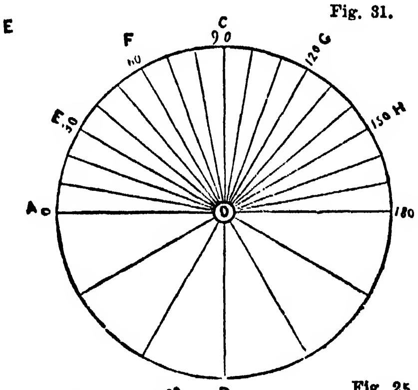


Fig. 31.



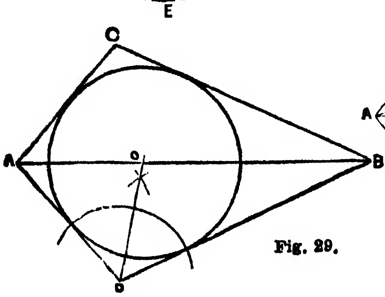


Fig. 29.

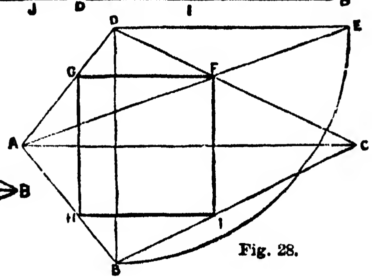


Fig. 28.

Fig. 30.

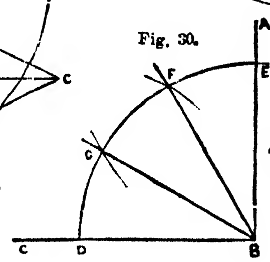
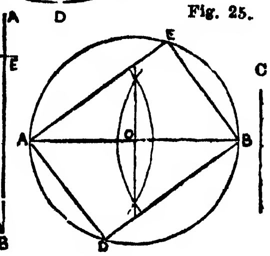


Fig. 25.



Draw the diagonal A B, which will bisect the angles C B D and C A D. Bisect the angle A D B. Produce the bisecting line until it cuts A B in O. Then O is the centre from which a circle may be described, touching all four sides of the trapezium.

Example No. 1 *of the foregoing* (Fig. 32).—To find the angle contained by the lines A B C.

Erect a perpendicular at B. Draw the quadrant D E, and trisect it. Divide the arc G E into three equal parts by points H and I (70° and 80°). Bisect the arc H I, and it will be seen

* The *Quatrefoil* is a figure based on four leaves or lobes. See remarks on the Trefoil (Fig. 11).

† *Trisect*: to cut into three equal parts.

that the line B C falls precisely on the bisecting point. A B C is therefore an angle of 75°. Had the line B C not fallen exactly in the bisecting point, further subdivision would have

Example No. 2 (Fig. 33).—To construct at a given point B an angle of a required number of degrees, say 100°.

At B erect a perpendicular, B C. Trisect the right angle, carrying on the arc beyond the perpendicular, C. Divide any one of the three divisions into three equal parts representing tens. Set off one of these tens beyond C, viz., to D. Draw B D. Then A B D will be an angle of 100°.

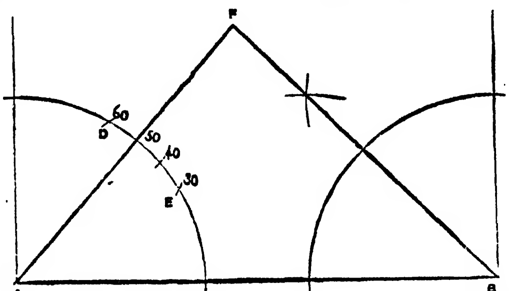


Fig. 34.

To construct a triangle, when the length of the base and the angles at the base are given (Fig. 34).—Let it be required that the base should be 2·5 (2, *decimal* 5, *or* 2 *and* 5 *tenths, which is* $2\frac{1}{2}$) inches long, that the angle at A should be 50°, and that at B 45°.

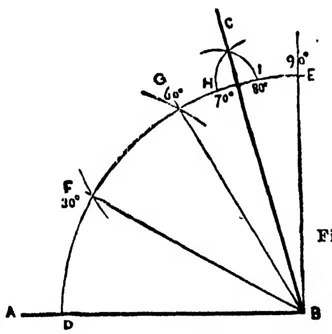


Fig. 32.

Draw the base 2·5 inches long. At A erect a perpendicular; draw a quadrant and trisect it in E D. Divide the middle portion, D E, into three equal parts, and the second division from E will be 50°. Draw a line from A through point 50, and produce it. At B erect a perpendicular, and bisect the right angle thus formed (as 45° is one-half of 90°). Produce the bisecting line until it meets the line of the opposite angle in F. Then A B F will be the required triangle.

e.—All the three angles of a triangle are always equal to two right angles, that is, 180°; and therefore, as one of the above angles is 50°, and the other 45°—total 95°—the vertical angle, that is, that opposite the base, will be 85°.

given to show its practical application. This has a short line marked at C, and two rows of figures round the rim—the one reading from right to left, and the other the reverse way.

In order to measure an angle by means of the protractor, place the edge A B on the straight line which is to form one of the sides of the angle, with the point C exactly against the point of the angle to be measured. Then the line C D will be seen to correspond with the point 60°, and B C D is therefore an angle of 60°; or, reading from the left side, A C D is an angle of 120°.

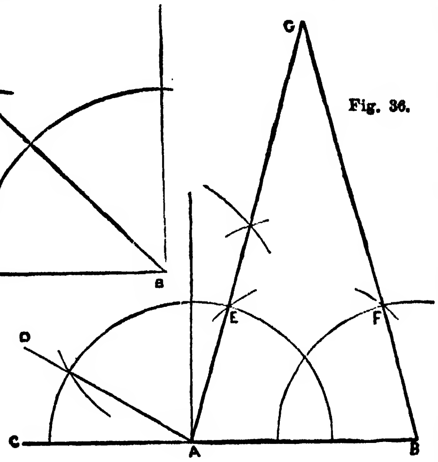


Fig. 36.

In constructing an angle, place C against the point at which it is desired to construct an angle; mark a point on your paper exactly against the figure corresponding to the number of degrees required; remove the protractor, and draw a line through the point thus obtained, to C, which will give the desired angle.

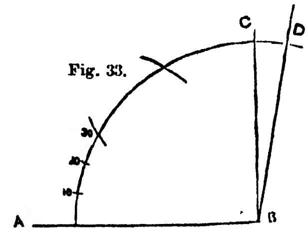


Fig. 33.

Protractors are sometimes made of wood or ivory, and of a rectangular form, as E F. These are used in a manner similar to the semi-circular instruments, but are not generally thought as useful or exact in practice.

To construct an isosceles triangle on a given base, and having a given vertical angle (say 30°). (Fig. 36.)

Before commencing to work this figure, it is desirable that attention should be called to the principle upon which the construction is based.

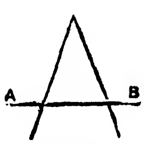


Fig. 39.

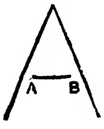


Fig. 38.

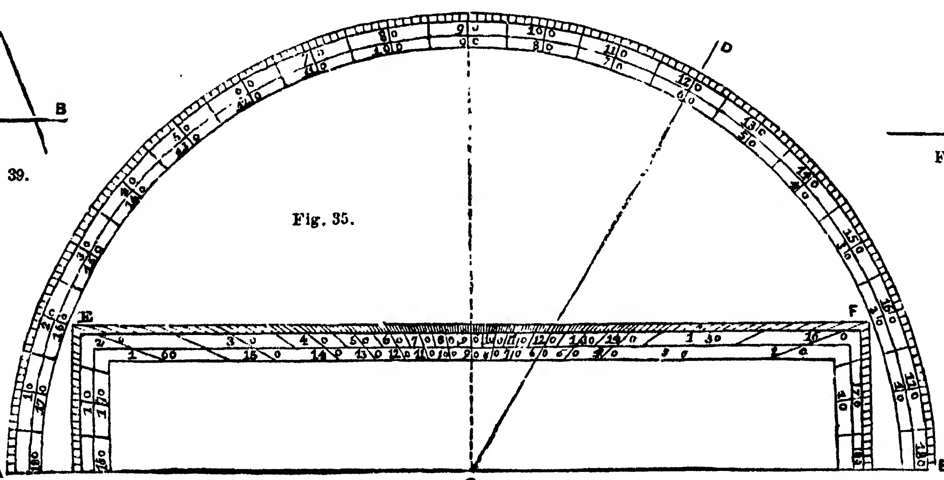


Fig. 35.

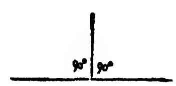


Fig. 37.

THE PROTRACTOR (Fig. 35).

For measuring and constructing angles there is in most cases of mathematical instruments a brass semi-circle called a *protractor*. This has been already referred to, and is here

It has been shown that all the angles of a triangle, of whatever shape it may be, will always be equal to two right angles (viz., 180°).

Every straight line then is equal to the bases of two right angles; for a perpendicular drawn at any point will at once form two right angles, equal to 180°, upon it (Fig. 37).

Now let it be supposed that £180 are to be divided between

three persons, *that one of them is to receive* £30, and the remainder to be equally divided by the other two.

It will be seen at once that, when the first condition has been fulfilled, and £30 deducted from £180, the remainder will be £150, or £75 for each of the remaining claimants.

It is on a similar principle that this operation is based; and this mode of procedure is rendered necessary because we cannot *commence* by constructing the vertical angle; for, as the base A B is fixed, we should not know *where* to commence the vertical angle, so that the sides might not cut through A B (Fig. 38), or pass beyond it (Fig. 39); and thus we are compelled to construct the angles at the base firstly, and of such a number of degrees, that they should meet in the required angle.

Now it has been shown that 180° stand on every line.

Returning now to Fig. 36, produce A B, and at A construct an angle of 30°—viz., C A D.

So that out of the whole sum of 180° we have set aside 30°, the fixed number.

Bisect the remaining angle D A B in E. Draw A E. At B construct an angle A B F, similar to the angle B A E.

Produce lines A E and B F, which will meet in G, and will form the required angle of 30°

NOTABLE INVENTIONS AND INVENTORS.

IV.—CLOCKS AND WATCHES (*continued*).

BY JOHN TIMBS.

THE middle of the fourteenth century seems to be the time which affords the first certain evidence of the existence of what would now be called a clock, or regulated horological machine; for although the term "horologia" had been of frequent occurrence in preceding ages, there is every reason to believe it was applied to other horological instruments. It appears from a letter written by Ambrosius Camalodunensis to Nicolaus of Florence, that clocks were not very uncommon in private families on the Continent about the end of the fifteenth century, and there is good reason for supposing that they began to become general in England about the same period; for we find in Chaucer, who was born in 1328 and died about 1400, the following lines:—

> "Full sickerer was his crowing in his loge,
> As is a clock, or an abbey orloge."

It is also believed, on good grounds, that a clock is not the invention of one man, but a compound of successive inventions, each worthy of a separate contriver. Thus, (1) wheelwork was known and applied in the time of Archimedes. (2) A weight being applied as a maintaining power would, in all probability, have at first a fly similar to that of a kitchen-jack, to regulate the velocity. (3) The ratchet-wheel and click for winding up the weight, without detaching the teeth or main wheel from those of the pinion in which they were engaged, would soon be found an indispensable contrivance. (4) The regulation by a fly, being subject to such great changes from the variations of density in the atmosphere, and the tendency of a falling body to accelerate its motion, would necessarily give rise to the alternate motion of the balance, with which invention an escapement of some kind must have been coupled. (5) The last-mentioned two inventions are most important ones, and would have induced such a degree of equability in the motion of the whole work, as would lead the way to a dial-plate, and to its necessary adjunct—a hand or pointer. Lastly, the striking part, to proclaim at a distance, without the aid of a person to *watch*, the hour that was indicated, completed the invention. And the supposition, that De Wyck's clock was a combination of the successive inventions of different individuals, is confirmed by analogy; for the clocks and watches of the present day have been brought to their present degree of perfection by a series of successive inventions and improvements upon what may now be called the rude clock of De Wyck, which is the most ancient clock of which we have a description. This—and, indeed, all clocks made with a balance for a regulator, without any regulating spring—must have been very imperfect machines; yet as early as 1484 a balance clock was used for celestial observations, and was superseded by the use of a portable one for ascertaining the longitude at sea, about 1530. Ancient clocks must have been reduced to a portable size prior to 1544, when the mainspring was substituted for the weight as a moving power; and this may be considered a second era in horology, from which may be dated the application of the fusee, round which is wound the chain or cord.

Among the earliest of the wheel-clocks seen in England was that of St. Paul's Cathedral, London, in 1286; and an agreement of 1344 shows that iron and steel were then used for the frame and clock, as they were until towards the end of the sixteenth century. The present clock at St. Paul's is remarkable for the magnitude of its wheels and the fineness of its works; it was made by Langley Bradley, at a cost of £300. It has two dial-plates, each between 50 and 60 feet in circumference; the hour numerals are a little over 2 feet in height; the minute-hands, 8 or 9 feet long, weigh 75 pounds each, and the hour-hands, between 5 and 6 feet long, weigh 44 pounds each. The pendulum is 16 feet long, and its bob weighs 180 pounds, but it is suspended by a spring no thicker than a shilling. Its beat is 2 seconds—that is, a dead beat, of 30 to a minute, instead of 60. The clock, going 8 days, strikes the hour on the brim of the great bell with a hammer; its head weighs 145 pounds, and is drawn by a wire to the back part of the clockwork, falling by its own weight on the bell, it can be heard at a distance of 22 miles; the clapper weighs 180 pounds; diameter of bell, 10 feet; weight, 102 cwt. Below this bell are the two quarter bells.

The Horse Guards' clock, we may here mention, made in 1756, was originally of coarse work. It was repaired and improved [illegible] measures time sufficiently accurate for practical purposes, not connected with astronomical observations; but much of its reputation is conventional, from its association with "military time" of the Horse Guards.

Clocks remained with balances for the motive power until the middle of the seventeenth century, when the pendulum was first applied—it is said by Galileo observing the oscillations of a lamp suspended in the cathedral at Pisa. The discovery is also claimed for Huygens, Bergen, Hooke, and others, about the same time; but the "ancient astronomers of the East employed pendulums in measuring the times of their observations, patiently counting their vibrations during the phases of an eclipse, or the transit of the stars, and renewing them by a little pressure of the finger when they languished; and Gassendi, Riccioli, and others, in more recent times, followed their example." ("Encyclopædia Britannica," 8th edit.)

"Clocks and watches," says Mr. Babbage, "may be considered as instruments for registering the number of vibrations formed by a pendulum or a balance. George Graham, in 1715, first applied a compensating power to counteract the effect of heat and cold upon the length of the pendulum; and John Harrison, in 1726, used different metals to compensate each other, the rods being placed in the form of a gridiron. The mechanism by which these numbers are counted is technically called a scapement. A common clock is merely a pendulum, with wheelwork attached to it to record the number of the vibrations; and with a weight, or spring, having force enough to counteract the retarding effects of friction and the resistance of the air. The wheels show how many swings or beats of the pendulum have taken place, because at every beat a tooth of the last wheel is allowed to pass. Now, if the wheel has sixty teeth (as is common), it will just turn round once for sixty beats of the pendulum, or seconds; and a hand fixed on its axis, projecting through the dial-plate, will be the second-hand of the clock. The other wheels are so connected with the first, and the number of the teeth on them so proportioned, that one turns sixty times slower than the first, to fit its axis to carry a minute-hand; and another, by moving twelve times slower still, is fitted to carry an hour-hand."

A few public clocks may be noted here. The Bank of England clock, in the roof, is a marvel of mechanism, as it is connected with all the clocks in the Stock Offices. The hands of the several dials indicate precisely the same hour and second, by means of connecting brass rods (700 feet long, and weighing 6 cwt.), and 200 wheels; the principal weight being about 300 lb. The General Post Office clock, by Vulliamy, is a beautiful work of art on a small scale; its pendulum-bob weighs 448 lb., and requires only 33 lb. to cause it to vibrate 2' 20" on each side of zero—an extremely small motive power. The clock of the Royal Exchange, manufactured by Dent in 1843, has been pronounced by the Astronomer Royal as "the best public clock in the world;" the pendulum, weighing nearly

4 cwt., is compensated, the first stroke of the hour is true to a second, and it can also be set to any fraction of a second. This was the first turret clock constructed by Mr. Dent. The Westminster Palace clock, designed by Mr. Denison, and made by Mr. Dent, jun., about 1855, has four dials, each 22 feet in diameter—the largest in the world with a minute hand; the great wheel of the going part is 27 inches diameter; the pendulum is 15 feet long, and weighs 680 lbs., and the scape-wheel weighs about half an ounce. This clock is said to be eight times as large as a full-sized cathedral clock; it requires two hours a week to wind it up, and reports its own time to Greenwich by electrical connection. In 1886 Sir Edmund Beckett—he had dropped the name of Denison when he succeeded his father in 1874 as fifth baronet—was raised to the peerage as Lord Grimthorpe.

PRINCIPLES OF DESIGN.—V.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

HAVING considered some of the chief principles involved in the production of decorative design so far as "expression" goes, we come to notice that constant adjunct, or handmaid, of form which has ever played an important part in all decorative schemes—namely, colour.

Form can exist independently of colour, but it never has had any important development without the chromatic adjunct. From a consideration of history, we should be led to conclude that form alone is incapable of yielding such enrichments as satisfy; for no national system of decoration has ever existed in the absence of colour. Mere outline-form may be good, but it is not satisfying; mere light and shade may be pleasing, but it is not all that we require. With form our very nature seems to demand colour; and it is only when we get well-proportioned forms which are graceful, or noble, or vigorous, in combination with colours harmoniously arranged, that we are satisfied.

Possibly this feeling results from our contact with Nature. The flowers appear in a thousand hues, and the hills are of ever-varying tints. What a barren world ours would appear, were the earth, the hills, the trees and the flowers, the sky and the waters, all of one colour! Form we should have, and that in its richest variety; light and shade we should have, with ever-varying intensity and change; but colour would be gone. There would be no green to cheer, no blue to soothe, no red to excite; and, indeed, there would be a deadness, although the world would be full of life, so appalling, that we can scarcely conceive of it, and cannot feel it.

Colour alone seems to have almost greater charms than form alone. How entrancing is a sunset when the sky glows with its radiant hues; the blue is almost lost in red, the yellow is as a sea of transparent gold, and the whole presents a variety and blending of tints, which charm, and soothe, and lull to reverie; and yet all form is indistinct and obscure. If so charming when separate from form, what is colour when properly combined with beautiful shapes? It is difficult, indeed, for many of those for whom I write to answer this question, even by a mental conception; for I could scarcely point to a single building in England which would be in any way a satisfactory illustration of what may be done by the combination of forms and colours. There is a beauty in Art, which we in England do not even know of: it does not exist round us, it is little talked of, rarely thought about, and never seen. A decorator is called in to beautify a house, and yet not one in fifty of the so-called decorators know ever the first principle of their art, and would not believe, were they told of the power of the art which they employ. They place on the walls a few sickly tints—so pale, that their want of harmony is not very apparent. The colours of the wall become the colours of the cornice and of the doors, because they know not how to produce a harmony of hues; and the result is a house which may be clean, but which is in every other respect an offence against good taste. I do not wonder that persons here in England do not care to have their houses "decorated," nor do I wonder at their not appreciating the "decorations" when they are done.

There are few objects to which colour may not be applied, and many articles which are now colourless might be coloured with advantage. Our reasons for applying colour to objects are twofold, and here we have the true use of colour. 1st. Colour lends to objects a new charm—a charm which they would not possess, if without it; and, 2nd, Colour assists in the separation of objects, and thus gives assistance to form. These, then, are the two objects of colour. Mark, first, colour is to bestow on objects a charm, such as they could not have in its absence. In the hands of the man of knowledge it will do so—it will make an object lovely or lovable, but the mere application of colour will not do this. Colour may be so applied to objects as to render them infinitely more ugly than they were without it. I have seen many a white bowl so coloured at our potteries as to be much less satisfactory when coloured than when white—the colouring having marred, rather than improved, its general effect. Here, again, it is knowledge that we want. Knowledge will enable us to transmute base materials into works of marvellous beauty, worth their weight in gold. Knowledge, then, is the true philosopher's stone; for if possessed by the artist it does, in truth, enable him to transmute the baser metals into gold. But a little knowledge will not do this. In order that we produce true beauty, we require much knowledge, and this can only be got by constant and diligent labour, as I have before said; but the end to be gained is worth the plodding toil. Believe me, there is a pleasure in seeing your works develop as things of beauty, delighting all who see them—not the illiterate only, but also the educated thinker—such as words fail to express. Although there is no royal road to art power, and although the road is long, and lies through much toil and many difficulties; yet as you go along, there is pleasure in feeling that one obstacle after another is cleared from your path, and at the end there is pleasure inexpressible. The second object of colour is that of assisting in the separation of form. If there is a series of objects placed near to one another, and these objects are all of the same colour, the beholder will have much more difficulty in seeing the boundaries or terminations of each than he would, were they variously coloured; he would have to come nearer to them in order to see the limits of each, were all coloured in the same manner, than he would, were they variously coloured: thus colour assists in the separation of form. This quality which colour has of separating forms is often lost sight of, and much confusion thereby results. If it is worth while to produce and place a decorative form, it is worth while to render it visible; and yet. how much ornament, and even good ornament, is lost to the eye through not being manifested by colour! Colour is the means whereby we manifest form.

Colours, when placed together, can only please and satisfy the educated when combined harmoniously, or according to the laws of harmony. What, then, are the laws which govern the arrangement of colours? and how are they to be applied? We shall endeavour to answer these questions, by making a series of statements in axiomatic form, and then we shall enlarge upon these propositions.

GENERAL CONSIDERATIONS.

1. Regarded from an art point of view, there are but three colours—*i.e.*, blue, red, and yellow.

2. Blue, red, and yellow have been termed *primary* colours; they cannot be formed by the admixture of any other colours.

3. All colours, other than blue, red, and yellow, result from the admixture of the primary colours.

4. By the admixture of blue and red, purple is formed; by the admixture of red and yellow, orange is formed; and by the admixture of yellow and blue, green is formed.

5. Colours resulting from the admixture of two primary colours are termed *secondary*: hence purple, orange, and green are secondary colours.

6. By the admixture of two secondary colours a *tertiary* colour is formed: thus, purple and orange produce russet (the red tertiary); orange and green produce citrine (the yellow tertiary); and green and purple, olive (the blue tertiary); russet, citrine, and olive are the three tertiary colours.

CONTRAST.

7. When a light colour is juxtaposed to a dark colour, the light colour appears lighter than it is, and the dark colour darker.

8. When colours are juxtaposed, they become influenced as to their hue. Thus, when red and green are placed side by side, the red appears redder than it actually is, and the green greener; and when blue and black are juxtaposed, the blue manifests

but little alteration, while the black assumes an orange tint or becomes "rusty."

9. No one colour can be viewed by the eye without another being created. Thus, if red is viewed, the eye creates for itself green, and this green is cast upon whatever is near. If it views green, red is in like manner created and cast upon adjacent objects; thus, if red and green are juxtaposed, each creates the other in the eye, and the red created by the green is cast upon the red, and the green created by the red is cast upon the green; and the red and the green become improved by being juxtaposed. The eye also demands the presence of the three primary colours, either in their purity or in combination; and if these are not present, whatever is deficient will be created in the eye, and this induced colour will be cast upon whatever is near. Thus, when we view blue, orange, which is a mixture of red and yellow, is created in the eye, and this colour is cast upon whatever is near: if black is in juxtaposition to the blue, this orange is cast upon it, and gives to it an orange tint, thus causing it to look "rusty."

10. In like manner, if we look upon red, green is formed in the eye, and is cast upon adjacent colours; or, if we look upon yellow, purple is formed.

HARMONY.

11. Harmony results from an agreeable contrast.

12. Colours which perfectly harmonise improve one another to the utmost.

13. In order to perfect harmony, the three colours are necessary, either in their purity or in combination.

14. Red and green combine to yield a harmony. Red is a primary colour, and which is a secondary colour, consists of blue and yellow—the other two primary colours. Blue and orange also produce a harmony, and yellow and purple; for in each case the three primary colours are present.

15. It has been found that the primary colours in perfect purity produce exact harmonies in the proportions of 8 parts of blue, 5 of red, and 3 of yellow; that the secondary colours harmonise in the proportions of 13 of purple, 11 of green, and 8 of orange; and that the tertiary colours harmonise in the proportions of olive 24, russet 21, and citrine 19.

16. There are, however, subtleties of harmony which it is difficult to understand.

17. The rarest harmonies frequently lie close on the verge of discord.

18. Harmony of colour is, in many respects, analogous to harmony of musical sounds.

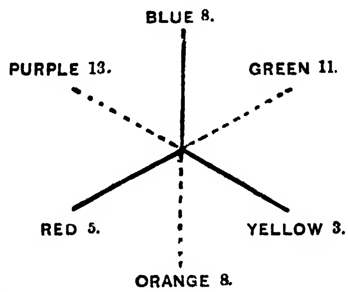


Fig. 17.

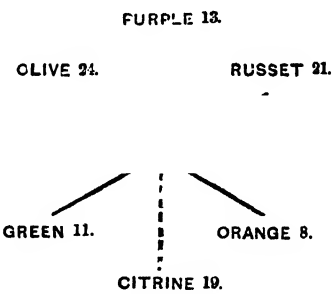


Fig. 18.

QUALITIES OF COLOURS.

19. Blue is a cold colour, and appears to recede from the eye.

20. Red is a warm colour, and is exciting; it remains stationary as to distance.

21. Yellow is the colour most nearly allied to light; it appears to advance towards the spectator.

22. At twilight blue appears much lighter than it is, red much darker, and yellow slightly darker. By ordinary gas-light blue becomes darker, red brighter, and yellow lighter. By this artificial light a pure yellow appears lighter than white itself, when viewed in contrast with certain other colours.

23. By certain combinations colour may make glad or depress, convey the idea of purity, richness, or poverty, or may affect the mind in any desired manner, as does music.

TEACHINGS OF EXPERIENCE.

24. When a colour is placed on a gold ground, it should be outlined with a darker shade of its own colour.

25. When a gold ornament falls on a coloured ground, it should be outlined with black.

26. When an ornament falls on a ground which is in direct harmony with it, it must be outlined with a lighter tint of its own colour. Thus, when a red ornament falls on a green ground, the ornament must be outlined with a lighter red.

27. When the ornament and the ground are in two tints of the same colour, if the ornament is darker than the ground, it will require outlining with a still darker tint of the same colour; but if lighter than the ground, no outline will be required.

ANALYTICAL TABLES OF COLOUR.

When commencing my studies both in science and art, I found great advantage from reducing all facts to a tabular form so far as possible, and this mode of study I would recommend to others. To me this method appears to have great advantages, for by it we see at a glance what it is otherwise more difficult to understand; if carefully done, it becomes an analysis of our work; and by preparing these tabular arrangements of facts, the subject becomes impressed on the mind, and we see the relation of one fact to another, or of one part of a scheme to another.

The following analytical tables will illustrate many of the facts stated in our propositions. The figures which follow the colours represent the proportions in which they harmonise:—

Primary Colours.		*Secondary Colours.*		*Tertiary Colours.*	
Blue	8	Purple	13	Olive	24
Red	5	Green	11	Russet	21
Yellow	3	Orange	8	Citrine	19

Primary Colours.	*Secondary Colours.*	*Tertiary Colours.*
Red 5, Yellow 3	Orange 8	Citrine, or Yellow tertiary 19
Blue 8, Yellow 3	Green 11	
Blue 8, Red 5	Purple 13	Russet, or Red tertiary 21
Red 5, Yellow 3	Orange 8	
Blue 8, Yellow 3	Green 11	Olive, or Blue tertiary 24
Blue 8, Red 5	Purple 13	

This latter table shows at a glance how each of the secondary and tertiary colours are formed, and the proportions in which they harmonise. It also shows why the three tertiary colours are called respectively the yellow tertiary, the red tertiary, and the blue tertiary, for into each tertiary two equivalents* of one primary enter, and one equivalent of each of the other primaries. Thus, in citrine we find two equivalents of yellow, and one each of red and blue; hence it is the yellow tertiary. In russet we find two equivalents of red, and one each of blue and of yellow; and in olive two of blue, and one each of red and yellow. Hence they are respectively the red and blue tertiaries.

Figs. 17 and 18 are diagrams of harmony. I have connected in the centre, by three similar lines, the colours which form a harmony; thus, blue, red, and yellow harmonise when placed together. Purple, green, and orange also harmonise (I have connected them by dotted lines in the first of the two diagrams). But when two colours are to produce a harmony, the one will be a primary colour, and the other a secondary formed of the other two primary colours (for the presence of the three primary colours is necessary to a harmony), or the one will be a secondary, and the other a tertiary colour formed of the two remaining secondary colours. Such harmonies I have placed opposite to each other; thus blue, a primary, harmonises with orange, a secondary; yellow with purple; and red with green; and the secondary colour is placed between the two primary colours of which it is formed; thus, orange is formed of red and yellow, between which it stands; green, of blue and yellow; and purple, of blue and red. In the second of the two diagrams we see that purple, green, and orange produce a harmony, so do olive, russet, and citrine. We also see that purple and citrine harmonise, and green and russet, and orange and olive.

* An equivalent of blue is 8, of red 5, of yellow 3.

WEAPONS OF WAR.—IV.

BY AN OFFICER OF THE ROYAL ARTILLERY.

SMALL ARMS (*continued*).

Before quitting the subject of muzzle-loading small arms, of which, together with the descriptions of powder used with them, we have given some account, it may be well to notice the means of ignition usually employed with arms of this class. Nearly the earliest and rudest mode of igniting the charge consisted of a fuse or slow match, which was applied to a small charge of powder placed over the "touch-hole," or vent, as it is now called. A grave inconvenience of this system consisted in the fact that arms could hardly be carried ready primed, at least for any length of time, because the priming was liable to drop out, or if it did not drop out, to become damp. Accordingly, the soldier was compelled to prime his gun just before using it; and as the operation had to be carefully performed, rapidity of fire under this system was out of the question; moreover, the carrying of an ignited match attached to the gun was a source of inconvenience and danger. The match was superseded by the flint-lock, the flint being made to strike a spark as it descended on to the priming charge of powder. In some instances a metallic alloy of iron and antimony was substituted for the flint. The action in both cases was the same; sparks being struck into the priming-charge. Here we come more closely to our present lock and hammer. A spring-lock was necessary to bring the flint violently down, and the hammer by which the flint was held was the direct parent of the hammer by which the percussion cap was afterwards fired. The next important advance consisted in the application of the percussion system to the firing of small arms. It is said that a Scotch gunsmith, called Forsyth, was the first who proposed a percussion fire-arm, for which he took out a patent in 1807; but it was not, we believe, until about 1822 that a percussion musket was introduced—at least in this country—for military use.

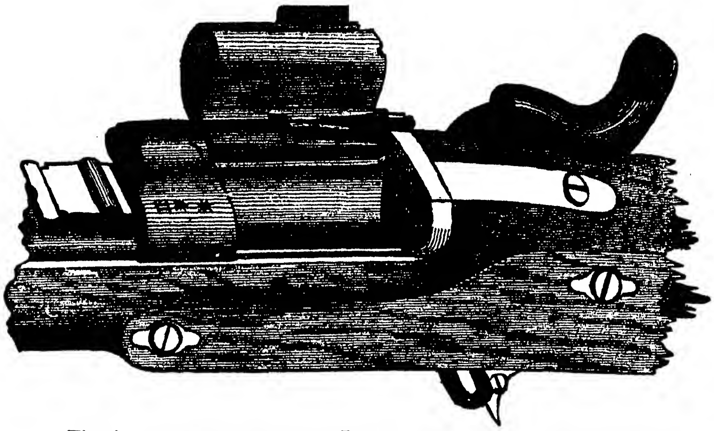


Fig. 1.—SNIDER RIFLE OPEN FOR RECEPTION OF CARTRIDGE.

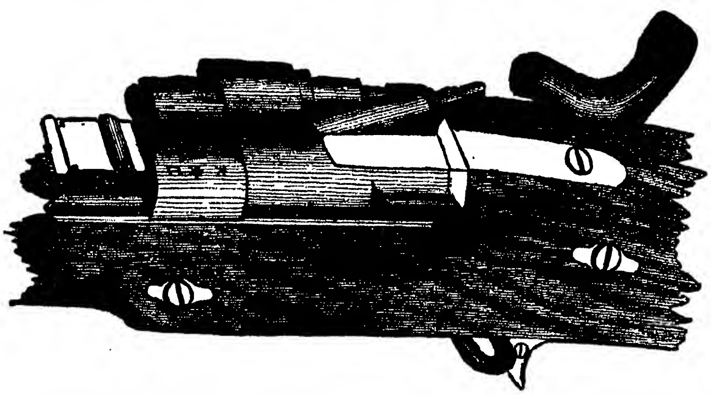


Fig. 2.—SNIDER RIFLE CLOSED AFTER INSERTION OF CARTRIDGE.

It is hardly necessary to insist upon the advantages which the percussion cap presents over the match- and flint-lock guns. A moment's consideration will serve to show that the change was a most important one, scarcely less important in its way than the introduction of breech-loading at a later period. To detail the various simplifications and improvements of the lock which have been effected would be tedious; nor is it necessary to set forth the endless varieties of percussion caps and devices for igniting fire-arms by means of detonating composition which have been proposed and attempted since the subject of this improved method of firing was first suggested about sixty years ago. It will be sufficient to say, that the percussion caps for military arms, with the form and appearance of which all our readers are no doubt familiar, are made of pure copper of a superior quality. It is not only necessary to use good copper, because a very small admixture of foreign matter, by affecting its malleability, will interfere with the production of a cap of the required form, but because too hard or brittle a metal would be apt to fly and injure the firer. Partly on this account, and partly because of the liability of zinc to corrosion, the proposition which has been frequently made to substitute that metal for copper has always been held to be inadmissible. For a similar reason our readers should be cautioned against employing, if they can avoid it, the cheap brass caps which are not unfrequently manufactured and coloured to represent copper. In the Government establishments very careful attention is paid to the selection of the copper.

Cap composition varies with different makers, and from time to time it has been altered for military arms. Thus, the composition consisted of—

	Parts.
Fulminate of Mercury .	4
Chlorate of Potash . .	6
Ground glass	2

—the latter ingredient being added to increase the sensitiveness of the composition, by promoting friction between the particles. When the Westley-Richards and Sharp's breech-loaders were introduced, with which the cap was required to ignite the powder contained in a paper cartridge, a more powerful composition was introduced, namely:—

	Parts.
Fulminate of Mercury .	4
Chlorate of Potash . .	1

This composition proved, however, too violent in its action for use on the nipples of the Enfield rifle, which are of a different form from the nipples of the breech-loading rifles, with which the caps were intended to be used, and a further change was made to a composition consisting of

	Parts.
Fulminate of Mercury .	6
Chlorate of Potash . .	6
Sulphide of Antimony .	4

The addition of the antimony secured the flash which was required to pierce the paper envelope of the cartridge, while at the same time it modified the intense violence of action of the cap, and prevented it from "flying" into pieces, and causing inconvenience and injury to the firer.

One more point with regard to percussion caps, and we pass on to another subject. This point is the waterproofing of the cap. Several methods have been tried, and are in vogue for rendering percussion caps waterproof; or, which is of more importance, for enabling them to resist damp. Among these may be mentioned the covering of the composition with a thin metallic disc, or with a disc of india-rubber. The simplest and probably the most effective plan is that which is applied to the Government caps, viz., to subject the composition to considerable pressure, by which means it is reduced to a stony hardness, and is rendered almost impervious to moisture; while by coating the composition with a strong varnish of shellac the caps are ultimately made completely waterproof.

We have now dealt generally with all the points which con-

nect themselves with muzzle-loading rifled small arms. We have considered the bullet, the charge, the means of ignition, the rifling, the weight and character of the arms. These elements, judiciously combined, gave us in the Enfield rifle a military weapon of great excellence. But there were two important directions in which improvements seemed necessary and possible. The first and most important consisted in increasing the rapidity of fire; the second in increasing the ballistic power of our weapons, an expression which covers all the shooting qualities of an arm—its accuracy, range, flatness of trajectory, penetrative powers, etc.—as distinguished from those qualities which connect themselves with easy and rapid loading, etc.

In short, the advantages of the Enfield rifle as an arm of precision were no sooner recognised than men began instinctively to endeavour to simplify and accelerate the operation of loading by introducing the cartridge at the breech. In the case of the cavalry soldier this was a matter of no small importance. The difficulties of loading a rifled arm on horseback were considerable; and thus we find that as early as 1857 steps had been taken towards the supply of breech-loaders to mounted men. In that year some Sharp's breech-loading carbines were issued to two regiments of cavalry. The charge in this arm was inserted bodily at the breech; and as the block ascended it cut off the end of the cartridge, and exposed the powder, which was fired in the same way as a muzzle-loader, with the ordinary percussion cap. The Sharp breech-loader, which was used for some time by our cavalry in India, is an extremely bad breech-loader, for several reasons—among them the great escape of gas which occurs at the breech on firing, and the employment of a percussion cap.

The Westley-Richards carbine was a great improvement on the Sharp, for the end of the cartridge was not cut off in loading, and the escape of gas was prevented by means of a felt wad attached to the back of the cartridge. In this wad we see a sort of rude prototype of the present non-consuming cartridge —an imperfect application of the present system of making the cartridge do the work of checking the escape of gas. We recognise here, also, in this half solution of the question, a dim perception of the fact now so fully admitted, that the cartridge is the turning-point or hinge upon which the success of a breech-loading small-arm depends. Here, for example, we have, in the Westley-Richards, a superior combination to that which existed in the Sharp; and why? Not because of the superiority of the breech-action of the Westley-Richards, for it may be doubted if the Sharp action (upon which the present admirable Henry breech-loader is based) is not in fact the better of the two. No; but simply because Westley-Richards was on the right track with regard to his cartridge, and Sharp was on the wrong track. It should here be mentioned that, as an arm of precision, the Westley-Richards carbine was a very good one. It was a "small-bore" rifle—an expression to which we will assign a definite meaning hereafter—and it threw a 400-grain bullet with a 2-dram charge, with great accuracy to a long range.

A rifle of this kind is open to several objections—among them, that it is fired in the old way by means of a percussion cap. So long as this mode of ignition is retained, it is impossible to realise the full advantages of a breech-loader. It is fair, however, to observe that it was through no fault of the inventors that this objectionable feature in the Sharp, Westley-Richards, and other breech-loading rifles was retained. The fact is that the authorities set their faces determinedly against cartridges containing—like those now in use for the Snider—their own means of ignition. It was supposed that such cartridges were liable to accidental explosion *en masse* by the ignition of a single cartridge in the barrel or box, and the consequences of such an accident were likely to be so serious that any cartridge of this description was considered inadmissible. We thus perceive that a serious barrier existed at this time to the development of the breech-loading question. It was regarded as essential to employ the old muzzle-loading means of ignition, and greatly accelerated rapidity of fire—one of the principal advantages of breech-loading, though not the only one —was impossible with a capping breech-loader; so that for several years the question was considered mainly as a cavalry question—facility, but not rapidity of loading being the thing aimed at. Indeed, rapidity of loading was rather deprecated than otherwise. Many good soldiers and experienced officers declared that if you gave a soldier a gun which he could load very quickly he would expend all his ammunition before he came within effective fighting range. It may be admitted that breech-loaders are open to this objection, although not to anything like the extent commonly supposed, and the objection is one which can be remedied by discipline and an effective, careful training. The practice of the Germans is an example of this. Here we have a nation which really understands the breech-loader, which is properly trained in its use and in the economical expenditure of ammunition, and the results we have seen in two great wars. On the other hand, we have the excitable, and, we may be permitted to add, badly-trained, ill-drilled, ill-disciplined French soldier, blazing away at any number of mètres from the enemy, and running out of cartridges early in the day. Cannot the English soldier do what the German does? Is our national temperament so excitable, so unlike that of the Germans, that no training can teach our men that the fighting unit is a man *plus* a cartridge, not a man by himself with an empty pouch? Then, again, it is to be observed that although a somewhat wasteful expenditure of ammunition may be one of the results of the introduction of breech-loaders, the non-issue of breech-loaders would be tantamount to the destruction of the army. If a soldier is likely to fire too rapidly in the one case, he is certain to be unable to fire rapidly enough in the other. The one defect may be corrected or controlled; the other, so long as muzzle-loaders are in use, cannot be. It is not a question of expediency, it is a question of sheer necessity. Whether or not breech-loading rifles may be attended with certain disadvantages is a point which admits of discussion, but it admits of no discussion that breech-loading rifles are vital to the very existence of an army. If the disadvantages are there they must be made the best of; and the way to make the best of this special disadvantage is so to train the soldier, so to drill and discipline, so to hammer at him, that he will come to understand that a shot ought never to be thrown away. And if he only act upon this principle, it will be no objection that he is able to fire a dozen shots a minute instead of three, and thus to do his work in one-fourth the time.

What we have written may appear to have an historical rather than a practical interest. A little consideration will, however, serve to show that this is not the case. It is in the history of the subject that its foundations repose. In the recognition of the difficulties which beset the earlier attempts, and the objections which stunted the growth of the question; in the perception of the growing importance of the cartridge question, and the relatively inferior importance of the breech mechanism; in the recognition of the fact that the question of breech-loading is quite distinct from and independent of the question of shooting—of ballistic power—we have the elements of the subject. Let us pass now to their practical application.

Up to about 1864 the question of breech-loading was treated, for reasons which we have endeavoured to trace in outline, as one which principally affected the cavalry soldier. But in 1864, instructed by the experience of the Dano-German war, General Russell's committee recommended that the British infantry be armed with breech-loaders. The question then arose, What breech-loader should be provided? We need not now trace all the discussion which took place at the time, or set forth the arguments which ultimately prevailed to secure the adoption of the Snider system of conversion. The Enfield rifle was thought, and properly thought, to be so excellent a shooting weapon, that it was considered that it would be sufficient, at least for the present, if this rifle were provided with an arrangement which, without affecting its shooting, would permit of its being fired more rapidly. In this way, while the British army could be rapidly re-armed with an effective breech-loader, ample time would be given for working out the question which would still remain of a totally new breech-loader for future manufacture. About fifty systems of conversion were submitted to Government, in reply to an advertisement dated August, 1864. Of the five systems which were preferred by the committee only one was a non-capping breech-loader, and that was the Snider. Ultimately, after some extensive trials, the Snider was adopted. Most of our readers are probably more or less familiar with the breech-action of the Snider rifle—the block hinged upon the side of the "shoe," and containing the piston or striker, by means of which the blow is communicated from the hammer to the cap.

Those who are unacquainted with this arm will be able to understand its construction from the illustrations on page 193.

The whole of the serviceable long and short Enfield rifles have been converted into breech-loaders on this system; and these, with the addition of some thousands of new Snider-Enfields, give us about 700,000 Sniders ready for use. The regular army and the militia were first armed with this weapon; and, when the Martini-Henry rifle replaced it, it was given over to the volunteers. The Snider rifle was subjected to a good deal of hostile criticism on its first introduction, which has been sufficiently answered by the experience of many years, during which it has stood the test of active and foreign service. It is obviously open to the objection that the calibre is too large, and that it is inferior as an arm of precision, and even as a breech-loader, to some of the more modern examples of military breech-loading arms; but the simplicity, efficiency, and durability of the breech mechanism are now universally admitted; and as for its shooting qualities, the weapon is at least as efficient as the Enfield rifle. With regard to the durability of these arms, it may be mentioned that the writer of these papers has seen several Snider rifles which have fired 40,000 and 50,000 rounds: he has seen one which has fired over 70,000 rounds, and which is still serviceable.

We have yet to speak of a very important element in the new arm—the cartridge. It is not too much to say that it is rather to the cartridge than to the breech mechanism that the arm owes its success. The breech mechanism, it should also be understood, was not an easy one to construct a cartridge for, because (1), in the event of a failure on the part of the cartridge, the block was liable to be blown open; (2) the difficulty—we might say, the impossibility—of making the block fit accurately and closely against the base of the cartridge rendered the strain upon the cartridge case peculiarly severe; (3) the extraction of the empty case had to be performed by hand, and without any leverage or mechanical assistance, and therefore must be easier than is necessary for guns in which "power" can be applied. But there were other conditions besides those of strength and easy extraction which the cartridge was required to fulfil. What they were, and how they have been satisfied, will be explained in another paper.

BUILDING CONSTRUCTION.—VII.

BRICKWORK (*continued*).

BRICKWORK should not be carried on in frosty weather, and even if such is expected, it is advisable, where possible, to delay the building. Unfinished walls should be covered with straw, on which boards, called *weather-boards*, should be laid. By attention to this simple matter injury to walls might often be prevented.

The introduction of substances other than those composing the walls should be as far as possible avoided. In general, however, some wooden members are required, but those should be treated with the greatest caution, so that they may not be crushed by the weight above them, or lest the superstructure, by being made to rest upon them, might become liable to sink should the wood decay. The principal wooden parts of the structure which are connected with the brickwork are the wall-plates, templates, lintels, and wood-bricks.

Wall-plates are pieces of timber laid lengthwise on the top of a wall to receive the ends of the floor-joists, which rest upon them. This will be fully treated of under the head of Flooring, and is only referred to in this place to explain the purpose of wall-plates in relation to the walls. It will be clear that if the joists were tailed singly on the walls themselves the pressure of each individual timber would be on a single brick and those which support it, whilst those between the joists would not in any way share the burden. The wall-plate then, resting as it does on the wall, distributes the weight over the whole length; and thus all parts of it bear alike. The application of a wall-plate will be shown in an illustration in a future lesson.

The purpose of *templates* (called also *templets*) is similar to that of wall-plates. They are used in a stronger form of flooring, which will subsequently be treated of, called "framed floors," the weight of which is borne by a few very large girders. Under these are placed the templates, which are stout pieces of timber two or three feet long; these, like the wall-plates, serve to spread the pressure over a wider surface than that on which the girders would otherwise rest.

Fig. 43 shows the section of a girder resting on a template. Now it is necessary, first, that pressure should be averted as much as possible from the end of this girder; for, in the event of damp striking it, or its rotting, it would give way under the weight. Secondly, the upper portion of the wall should receive no support from the girder by resting on it; for, should the

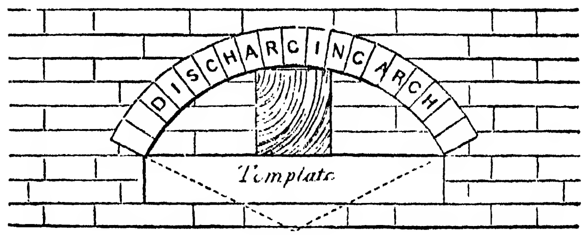


Fig. 43.

girder warp, sag, or by any means shake, the brickwork dependent upon it would crack and give way. The arch, then, turned over the end of the girder and lintel, not only supports the wall above, but "discharges" the weight over the walls on each side.

Lintels are pieces of timber placed over the square-heads of windows; they are used to preserve the square form, and for the attachment of the wooden lining of the under surface of the opening called the *soffit*, etc. They should not, however, be allowed to bear the weight of the wall above, under which they would certainly give way; and any sagging in the middle would cause their ends to rise, by which the entire brickwork would be disturbed. It is therefore necessary to build "discharging" arches over them. The principle on which arches are constructed will be considered further on; it is therefore only necessary here to demonstrate their use in relieving the lintel from pressure.

Fig. 44 illustrates the position of a lintel, over which a discharging arch is placed, for the same purpose as that above. This cut also shows the application of *wood-bricks*, W, W. These are used for the attachment of joiner's work in the jambs

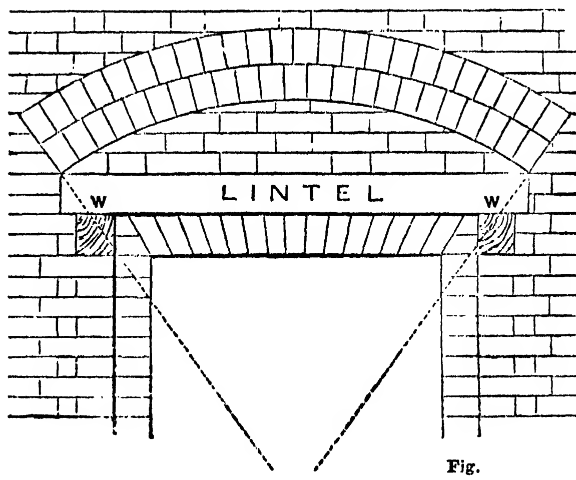


Fig.

of the windows and doors, for their fittings, and along the walls at certain heights for the skirtings or wainscoting to be nailed to. It is scarcely necessary to remind workmen that it is worse than useless to drive nails into mortar between bricks; and that therefore when it is necessary to drive a nail into a wall already built, the wall must be *plugged*, that is, wedges of wood must be driven in, and into these the nails may be hammered. But the use of wood-bricks supersedes the necessity of wedges in a wall in course of building, and as it is known beforehand what fittings are to be attached, the blocks of wood

cut to the exact shape and size of the bricks can be worked in as bricks at the points in the wall where they will be required by the joiner.

Wood-bricks are, however, gradually going out of use. It is found better to insert a piece of timber of the thickness of the joint of the brickwork—viz., about $\frac{1}{4}$ or $\frac{3}{8}$ thick, which shrinks less than a wood-brick, and still affords sufficient hold for the nails.

Bond-timbers are long pieces of wood like continuous wood-bricks. They are not much used now. Their purpose is to bond the bricks together, and for the attachment of mouldings, wainscoting, etc.; but they are liable to shrink, swell, and decay, according to the situation in which they may be placed; and further, in the event of taking fire, they burn away, and thus the wall resting on them is weakened. Their use in England is now almost entirely superseded by hoop-iron. Thin and narrow strips of this metal, tarred, are laid in the bed-joints of the mortar, at intervals more or less frequent, according to the thickness of the wall; and they are found in every way effective, whilst it has been shown that the joiner's fittings may be attached to single wood-bricks, on which so much structural strength or safety does not depend.

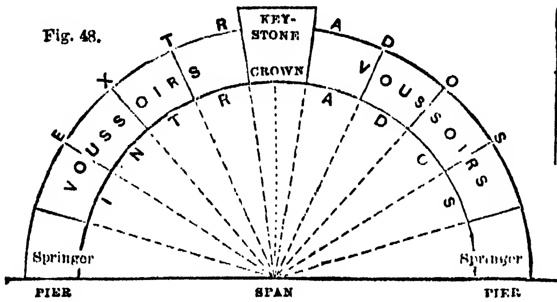


Fig. 48.

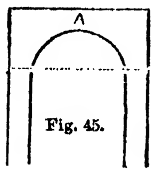


Fig. 45.

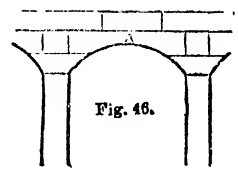


Fig. 46.

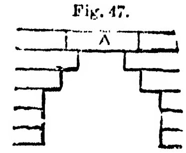


Fig. 47.

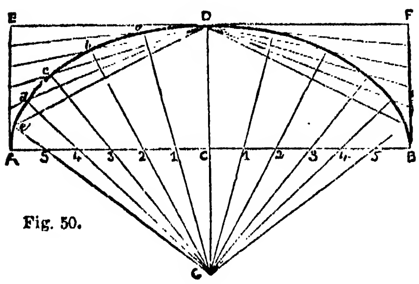


Fig. 50.

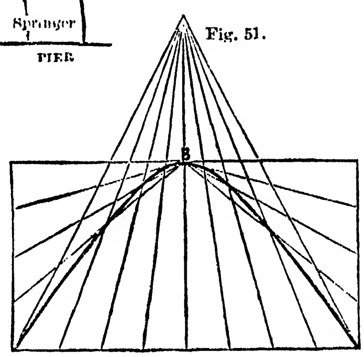


Fig. 51.

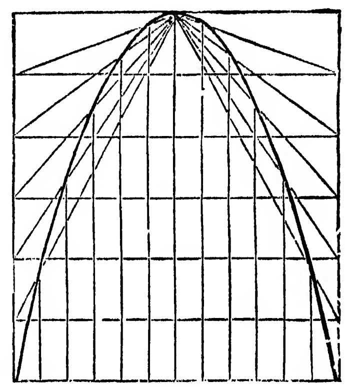


Fig. 52.

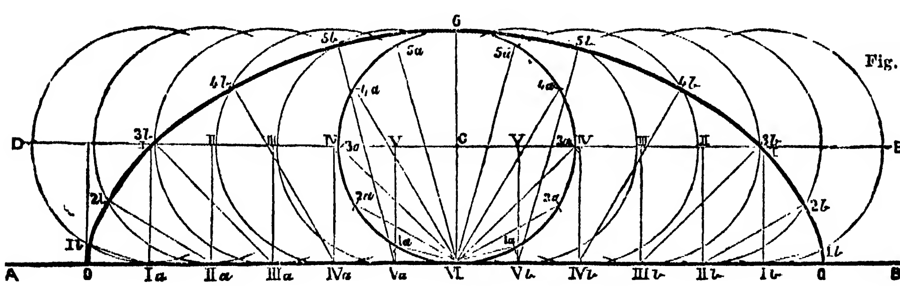


Fig. 53.

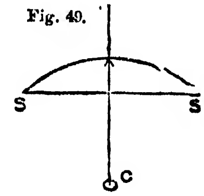


Fig. 49.

ARCHES.

Arches have been incidentally spoken of, but they form such an important feature in building construction, that it is deemed advisable that they should be treated of separately. It is necessary, then, that the student should have a very clear conception as to what an arch really is. For if a positive conclusion has not been arrived at, and if the "arch principle" is not thoroughly understood, he cannot be expected to design an arch, or to construct it with accuracy or intelligence, even if designed by another. Let us then state once for all, that every curved covering to an aperture is not necessarily an arch. Thus, the stone which rests on the piers shown in Fig. 45 is not an arch, being merely a stone hewn out in an arch-like shape; but at its top, the very point (A) at which strength is required, it is the weakest, and would fracture the moment any great weight were placed upon it.

Equally faulty is the annexed example of an early Egyptian attempt (Fig. 46), in which the first course of horizontal stones projects beyond the piers, and on these rests a third, hewn out to complete the form; and here again we have weakness where strength is required.

At Etruria and Phigaleia constructions similar to Fig. 47 have been found, which are, if possible, worse in principle than the previous ones; for it is clear that, unless the upper slab be longer than the width of the opening, and the lower stones are weighted at their tail ends, the whole must fall in the moment any weight rests on A.

We come, then, to the point at which it is required that we should state, as briefly as possible, what an arch really is.

An arch, then, is an assemblage of stones or bricks, so arranged that they may by mutual pressure support not only each other, but any weight that may be placed upon them.

The leading principles in the construction of an arch are—

1. That all the stones of which it is formed shall be of the form of wedges; that is, narrower at the inner than the outer end.

2. That all the joints formed by the meeting of the slanting sides of the wedges should be radii of the circle, circles, or ellipse, forming the inner curve of the arch, and will therefore converge to the centre or centres from which these are struck.

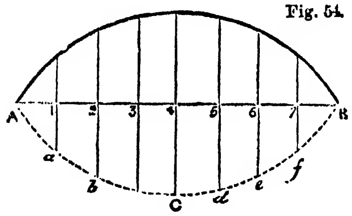
These two brief statements will serve at the present stage to

make clear to the mind of the student the general principles of an arch; the mathematical reasonings connected with the designing of arches to bear certain weights are omitted, as not coming within the scope of this course of lessons, but the writer is very anxious that the student should clearly comprehend and not misconstrue the cause of this omission. It is *not because he deems this mathematical knowledge unnecessary*, but simply because he wishes to give information to students who have not had opportunities of acquiring such. Elementary works on the various mathematical subjects connected herewith can, however, be easily obtained; and all who would really study principles, and appreciate the exquisite refinement of the examples herein given, are strongly urged to read them.

Referring to Fig. 48, we shall first explain terms. The under surface is called the *intrados*, and the outer the *extrados*. The supports are called the *piers* or *abutments*, though the latter term is one of more extensive application, referring more generally to the supports which bridges obtain from the shore on each side than to other arches. The term *piers* is, as a rule, supposed to imply supports which receive *vertical* pressure, whilst "abutments" are such as resist *outward* thrust. The upper parts of the supports on which an arch rests are called the *imposts*. The *span* of an arch is the complete width between the points where the intrados meets the imposts on either side; and a line connecting these points is called the *springing* or *spanning line.*

The separate wedge-like stones composing an arch are called *voussoirs*, the central or uppermost one of which is called the *key-stone;* whilst those next to the imposts are termed *springers*.

Fig. 54.



The highest point in the intrados is called the *vertex* or *crown*, and the height of this point above the springing line is termed the *rise* of the arch. It will be evident that in a semicircular arch, such as Fig. 48, this would be the radius with which the semicircle is struck. The spaces between the vertex and the springing line are called the *flanks* or *haunches*.

The following are the varieties of arches used:—

The *Semicircular*, as shown in Fig. 48; the *Segment* (Fig. 49), in which a portion only of the circle is used—the centre C is therefore *not* in the springing line S, S; the *Elliptical* (Fig. 50); the *Hyperbolical* (Fig. 51); the *Parabolical* (Fig. 52); the *Cycloidal* (Fig. 53).

The methods of constructing these various curves are fully elucidated and illustrated in the lessons in "Practical Geometry applied to Linear Drawing," and it is therefore not necessary to repeat them in this place.

The *Catenarian* (Fig. 54), the form of which is the reverse of the curve taken by a chain or heavy rope when suspended between two points, as A B. A simple mechanical method of describing this curve is as follows:—Draw the springing or spanning line, A B, and bisect it by a perpendicular; place your drawing-board upright, and having marked on the central perpendicular the length 4 C, equal to the height of the required arch (the *rise*), fasten a cord at A; place a nail at B, and, suspending the cord over it, draw it until it gradually reaches C; then fasten it, and with your pencil carefully trace the curve thus formed, being guided by, but not disturbing the cord, which should be first *wetted* and drawn between the fingers. A further improvement on this method is to obtain a quantity of shot, drilled through their centres like beads, and thread them on a fine flexible cord, such as silk, having previously slightly rubbed them over with common black lead. When this loaded cord has been accurately placed, press gently on the shot, and thus a series of marks will be made on the paper. The curve drawn through these points will be the *Catenary*.

Now set off any number of divisions on each side of the centre, and draw perpendiculars through them, cutting the curve in *a*, *b*, *c*, C, *d*, *e*, *f*, and passing through the span A B in 1, 2, 3, 4, 5, 6, 7; set off all the perpendiculars *above* the spanning line, the lengths of 1 *a*, 2 *b*, 3 *c*, etc.; join these points, and the curve will be the catenary inverted, as used in the catenarian arch.

CHEMISTRY APPLIED TO THE ARTS.—IV.

BY GEORGE GLADSTONE, F.C.S.

CALICO PRINTING.

CALICO printing forms now one of the greatest industries of the country, and is destined steadily to increase as the great foreign markets become more and more opened up to British commerce. It is associated with the names of many of the wealthiest families of Lancashire and Glasgow, such as the Peels, whose enterprise in availing themselves without delay of every improvement in the art, led to the realisation of that fortune which enabled the late statesman to devote himself to a public career.

From the earliest ages down to the end of last century, what is termed "hand-block printing" was universally practised, and it still continues to be to some extent. Block printing by machinery has since been introduced; but though the machines employed for this purpose are very ingenious and beautiful, they would never have sufficed to meet the rapidly increasing demands of the trade. It is to the invention of the cylinder machine that the prosperity of our manufacturing districts is so largely indebted.

Block printing, as distinguished from cylinder printing, consists in stamping the calico with a pattern raised in relief upon the block, after being moistened with the composition which is intended to be transferred to the cloth. The hand-block varies somewhat in size, according to the pattern or work required; but it is commonly about nine inches long and six broad, with a handle for the sake of convenience. The pattern is sometimes cut out in relief upon the wood, but this is liable to wear down very rapidly, so that it has been found greatly preferable to raise the pattern on the block, by inserting strips of copper of the desired form and thickness into the wood, by which means a sharper and more durable design can be obtained. The mordant, or dye stuff, as the case may be, is applied to the block by pressing the latter upon what is termed a "sieve" (a box covered with woollen cloth), which is kept moist by the composition below working its way up through the interstices, and then the cloth is stamped with it at the regular distances required to produce the pattern. Another mode of charging the block with the dye is to pass a moistened roller over it, after the manner generally adopted for applying ink to letter-press. Several colours may, however, be printed simultaneously with one block; in which case the sieve must be divided into as many compartments as may be required, each division corresponding in shape and size with the portion of calico which is to receive a certain mordant or dye. If the several colours are to form parallel lines, whether straight or waved, the roller can also be readily adapted to this purpose. A piece of print would ordinarily require about 450 separate applications of the hand-block, involving a very serious expense for labour, as well as occupying a considerable time; especially as each impression must be adjusted with the utmost nicety, or there will appear to be breaks or irregularities in the pattern. In order to increase dispatch, and at the same time to secure great precision in the joining of the pattern, machinery has been adopted; the most complete invention of the kind being the "Perrotine," so named because it was brought to perfection by M. Perrot, of Rouen, one of the chief centres of the French cotton manufacture.

Cylinder printing has now almost superseded all the other processes, those previously employed having no chance of competing with it, either as to precision or dispatch. It dates from about the year 1785. It differs in several particulars from the block system. In the first place, the pattern is not raised upon the cylinder, as in the block, but cut into it, by which means fine lines can be produced without suffering much from wear and tear; in the second, it can be arranged with such precision that the pattern shall be continuous; and in the third, the printing can go on without intermission, so that there is an immense saving of time. The multiplication of different colours in one pattern can also be much more easily effected by the adoption of this system, as almost any number of cylinders can be adapted to the machine, according to the number of colours desired.

The following description of the actual operations will be confined to cylinder machine printing, as the block system varies from it only in the mechanical arrangement. The several

processes which a piece of goods ordinarily passes through at a printing establishment consist of singeing, bleaching, printing, stoveing (in which ageing is included), dunging, dyeing, brightening, and dressing. There are, however, some special processes adopted to produce different styles, which will be described afterwards. They may be regarded as additions to or variations from the ordinary style.

Printing.—It will be seen at once that the result depends upon the same chemical reactions as have been fully explained in the previous articles upon Dyeing; and it will be necessary to bear in mind the special functions of mordants and alterants. The colours which the piece of goods is hereafter to assume are not printed upon it, but only the mordants, which are to take them up afterwards, and to fix them. The pattern being engraved upon the copper cylinder, it has to be charged with the mordant, which must be of such a consistency that it will neither run too freely, nor stick to the metal. With this object, it is usually thickened with flour, starch, pipeclay, sugar, glue, gum, etc., but the quantity of such ingredients varies a good deal, according to the character of the design; and the thickenings themselves must be selected with reference to the substances contained in the mordants, some of the salts used for this purpose causing starch or flour to coagulate, while others have the same effect upon gums—which renders them quite unfit for the purpose. The mordants have, of course, to be likewise selected with reference to the colours which it is intended to produce, so that, on subsequently steeping the cloth in the dye, different chemical reactions may take place, and thus bring out the variety of colours or shades required. Thus mordants made with iron salts and alums in various proportions will serve to produce all kinds of tints from red to purple, and even to brown: by omitting the alum altogether, a black may be produced; and, on the other hand, an aluminous compound without any iron salts will serve as a mordant for orange. Each cylinder employed, being arranged so as to fit into its exact place in the pattern, and charged with its respective mordant, passes over the cloth in succession, discharging the mordant upon it, which then passes at once into another chamber, in order to undergo the next process. The printing, however, cannot be satisfactorily performed unless the cloth be damp, a certain amount of moisture being absolutely necessary in order to ensure the mordant's thoroughly adhering to the fabric; but if, on the contrary, it should be made too wet, the mordant would be liable to run, and the sharpness of the pattern would be marred. In order that the proper medium should be secured, and that the whole piece should be of uniform dampness, it is found best to let the goods lie in a damp atmosphere for some time, and that the printing-room should be maintained at a pretty high temperature with the air thoroughly saturated with moisture.

Stoveing.—Immediately after coming off the printing-machine, the cloth is passed through a hot flue, in order to dry the substance taken off the cylinders before it has time to spread, which action would be encouraged by the dampness of the fabric. In the act of drying, the mordants adhere more closely to the fabric, especially if acetates of iron have been used, the acetic acid being driven off by the heat, and leaving the iron free to unite with the cloth. The hot flue leads into the ageing-room, where the cloth remains suspended for about a couple of days, to complete the fixing of the mordants, so far as exposure to the influence of the atmosphere will carry the process.

Dunging.—This is a very necessary operation, and is so named from cow-dung being usually the material employed for the purpose. Other ingredients are sometimes used as substitutes, and there are cases also when a bran-bath will suffice. The valuable properties of the dung appear to consist in the phosphorus compounds and the albuminous matters contained in it; and the natural combination is preferable to the chemical preparations which are in some instances used instead. The result produced is a double one; it fixes more thoroughly the iron salts and aluminous mordants which have been transferred to the cloth in the act of printing, while at the same time it carries off the ingredients which have been introduced as thickenings, so as to expose the mordants to the full action of the dye which is presently to be applied. It is usual to pass the goods rapidly through two separate baths made of a solution of this material in warm water, the tanks being arranged with a series of rollers on each side, over which the fabric is drawn alternately, so that a very large surface is exposed to the action of the bath. After each of these immersions the goods should be well scoured in the dash-wheel (similar to what is used in bleaching), so as to carry off the extraneous matters.

Dyeing.—Up to this stage, although the pattern has been printed upon the cotton, the effect is not manifest, the slight colour which may have been conveyed to the cloth with the mordant having no reference to that which is intended to be ultimately produced. This comes out during the dyeing; the mordanted portions of the cloth—which exactly correspond with the pattern, or combination of patterns, engraved upon the cylinders—taking up the dye, and producing, with the various mordants employed, the variety of colours required to produce the desired result. The chemical processes upon which this depends will be readily understood by those who have read the previous articles on Dyeing, but the practical details will need some further description. One of the dyes most commonly used is madder, or alizarin. A solution of it is made in the dyebeck—a long vessel containing the dye in solution, above which a roller or reel extends for its whole length, over which the cloth passes; and, being made to revolve by a winch, it carries the fabric with it, so that the whole surface becomes equally exposed to the action of the dye, and by repeated revolutions has as large a surface as possible brought under its influence within a given time. The immersion in the dyebeck should occupy four or five hours, during which period the temperature should be gradually raised from a tepid to the boiling heat. The addition of a little chalk, especially if the water should be very pure, greatly heightens the effect of the madder. Should it be intended that the mordant printed from any one cylinder shall take up no other dye than madder, the process above described must be repeated until the mordant is thoroughly saturated, so that it may be rendered incapable of taking up any of the dyes to be subsequently applied for other parts of the pattern. Suppose, however, an orange be desired, the maddering would be stopped sooner, in order that some of the mordant might remain free to combine with the yellow dye. The same plan is adopted when solutions of quercitron, sumach, and other dye stuffs are used.

Brightening.—The next step (sometimes called "clearing") is for the purpose of bringing up the colours to their full brilliance, and at the same time of finishing the operation of fixing. This is attained by passing the goods through a soap bath two or more times, according to the dyes which have been previously applied, the second immersion being usually in a slightly acid solution. Between each bath the fabric should be thoroughly rinsed and exposed to the air. The effect of these operations is to clear the unmordanted portions of any colour that may be adhering to them, so as to obtain a perfectly white ground, and also to discharge from the rest of the surface any excess either of mordant or dye which has not entered into combination with the other. Some dyes, however, will not bear the action of soap, and for clearing these a bath of bran is used instead, the goods being immersed for about half an hour, during which time the liquor is raised to the boiling-point. After this they only require dressing, in order to give them a proper finish for the market.

Such is a brief description of the process in most general use for printing calicoes. The ingredients principally employed as mordants are alumina and the salts of tin and iron, different combinations of which are worked up with gum and other thickenings, in order to make the various pastes for feeding the cylinders upon which the several parts of the required pattern are engraved. The dye-stuffs which are subsequently used for producing a permanent colour with the various mordants have already been named in the articles on Bleaching, the calico printer having to consider the varied affinities of certain dyes for the several mordants which have been used in printing the pattern, so that they shall produce such colours, or combinations of colour, as shall make a harmonious whole. Madder, cochineal, and safflower are much used for various shades of red; chromium, yellow berries, and quercitron, for yellows and orange; the double cyanides of potassium for blue; while combinations of these, by successive applications in the dyebeck upon appropriate mordants, will produce the intermediate colours. The selection of the most suitable dye-stuffs, so as to realise the best effect, is a matter of considerable importance;

nor is the order in which the dyes are applied a matter of indifference, the general rule, however, being that the darkest colours should be dealt with first.

There are yet other processes connected with calico printing to be described, which must form the subject of another article.

TECHNICAL DRAWING.—XIII.

DOVETAILING.

We do not know any branch of carpentry or joinery which so much shows whether the workman is a "good hand" or not, as the way in which he joins timber at the angles. We say "carpentry and joinery," because carpenters are constantly called upon to build wooden cases for cisterns and similar constructions; and, therefore, this lesson refers to them as well as to joiners. Certainly it applies to all *young* workmen, for they, above all, must learn accuracy in joining, and must acquire the power of cutting wood, so that every part may fit without being hacked, chopped, chiselled, or shaved, by which material, time, and patience are wasted, and, in consequence, bad work ensues. It is, of course, desirable that a joiner should work *quickly;* but it is by far more important that he should work *well;* that he should join his materials with firmness and accuracy; that he should make the surfaces perfectly even and smooth, the mouldings true and regular, and the parts intended to move so that they may be used with ease and freedom.

It is also of the greatest importance that the work when thus put together should be constructed of such dry and sound materials, and on such principles, that the whole should bear the various changes of temperature and of moisture and dryness, so that the least possible shrinkage or swelling should take place, and that frames, panels, or doors should not warp or twist. We have seen the great effects of encouraging good workmanship in iron and in the construction of machinery, which is now one of the industries for which this country is famed throughout the world: let us attach the same importance to our wood-work, and there is no reason why we should not in that branch attain a similar position.

One of the most important methods employed by the joiner is that termed *dovetailing,* which is of three kinds—namely, common, lap, and mitre. *Common dovetailing* shows the form of the pins or projecting parts, as well as the excavations made to receive them. Fig. 108 shows the ends of the two boards, *a* and *b*, to be thus joined, and Fig. 109 shows the joint completed. Fig. 110 represents a variation of this form, used in attaching the fronts of drawers to the sides, and for similar purposes. Here the dovetail is shown on the one side only, a ledge being left at the end of *a* so that the ends of the dovetails of the side *b* do not penetrate quite to the front.

Lap dovetailing is similar to this, but in that system the ends of the dovetails of the side *a* are shortened, and the recesses which are to receive them in *b* are not cut through; when joined together, therefore, only the ledge is visible on the return side.

Mitre dovetailing—sometimes called also *secret dovetailing*—conceals the dovetails, and shows only the mitre at the edges. The manner in which this joint is effected will be understood from Fig. 111, in which the two parts A and B are given, each part being lettered to correspond with the position it is to occupy when the sides are joined. Concealed dovetailing is particularly useful where the faces of the boards are intended to form a salient angle, that is, one which is on the *outside* of any piece of work; but where the faces form a re-entrant angle—that is, a joint to be seen from the *inside*—common dovetailing will answer best; for, first, it is stronger, because the dovetails pass entirely instead of only partly through; secondly, it is cheaper, for the dovetails which go through the whole wood take up so much less time in working than where a mitre has to be left; and further, if well executed, the dovetails are, by the very nature of the work, concealed internally.

Fig. 112 exhibits a method of joining two boards at right angles to each other. This is the simple mortise and tenon, and will not require any explanation.

MOULDINGS.

Mouldings are classed as Roman, Grecian, and Gothic.

The Roman mouldings are all formed of parts of circles, and can therefore be struck with compasses. The Grecian are principally composed of parts of curves known as the *conic sections*—such as the ellipse or hyperbola. They are otherwise nearly similar to the Roman, which are therefore illustrated in this place as being the simpler and the more generally used. The modes of describing the conic sections will be found in the lessons in "Practical Geometry applied to Linear Drawing."

Fig. 113.—The moulding of which this is a section is called the *Ovolo*, or quarter round. The fillet, or straight edge projecting beyond the curved portion, is to be drawn first, and then the horizontal, which represents the depth or bottom line of the moulding. Now produce the bottom line of the fillet, and on it, from the point at which the curve is to start, mark off the width of the moulding. The point marked ⊙ in the cut, is the centre from which the quadrant is to be struck.

Fig. 114 is called the *Torus*, or half-round. Having drawn the fillet, and the line representing the bottom of the moulding, draw a line at right angles to these. Bisect the width of the curved part, and the bisecting point will be the centre.

Fig. 115 is the *Cavetto*, or hollow. This is a quarter-round, the curve turning *inward*. It is thus precisely the reverse of the ovolo.

Fig. 116 is a section of the moulding called the *Cyma Recta*. The exact form of this moulding is to a certain extent a matter of taste, since the curve may be made more or less full, as shown in the three examples, Figs. 116, 117, and 118. To describe Fig. 116, draw a perpendicular across the depth of the moulding, and bisect it. From the bisecting point as a centre point describe a quadrant; through the centre draw a horizontal line, and from the point where the quadrant already drawn touches this line mark off the radius; then from this point as a centre describe the second quadrant, which will complete the form. In this and the subsequent curves composed of combined arcs the greatest care is necessary, so that the one may glide smoothly into the other without showing any break or thickening at the joining. To describe the Cyma Recta shown in Fig. 117, which is the form most generally used, let n and o be the points to be united by the moulding. Draw the line $n\,o$, and bisect it; with half $n\,o$ as a base describe an equilateral triangle on the opposite sides of the line; then the apices* of the triangles will be the centres from which the curves are to be struck.

To describe Fig. 118, or others the curves of which are required to be more flat than in the last figure, draw the line $n\,o$ as before, and bisect it. Bisect these two divisions again, and the centres will be on these bisecting lines, according to the form required; for, of course, the longer the radius the flatter the curve will be.

If it is required that the curve should be more full at the lower than at the upper part, it may be effected in the following manner, which is shown in Fig. 119. Having drawn $n\,o$, divide it into *three* equal parts; construct an equilateral triangle, the base of which is two of these thirds, and on the opposite side of the line another, the base of which is the remaining third. The apices of these triangles will be the centres for the curves.

Fig. 120 is the *Cyma Reversa*. In this moulding the curve bulges outward at its upper part, its fulness being regulated by the taste of the designer. Thus it may be formed of two quadrants, as in Fig. 120; or of two semicircles, as in Fig. 121; or it may consist of the two arcs drawn from the apices of triangles, as in the cyma recta already shown.

Fig. 122 is the *Scotia*. This is a hollow moulding, sometimes consisting of a semicircle only—viz., the reverse of the torus. In other instances, as in Fig. 122, it is composed of two quadrants; and in others it is drawn from three centres, as in Fig. 123. To draw this, divide the depth of the moulding into three equal parts, and with one third describe the quadrant $r\,u$; produce the horizontal $r\,u$, and from r set off i, equal to half $u\,r$. At n erect a perpendicular, and mark on it $n\,k$, equal to $i\,u$; draw $i\,k$, and bisect it; produce the bisecting line until it cuts $n\,k$ in s. Draw $s\,i$, and produce it. From i, with radius $i\,u$, draw the next portion of the curve, meeting $s\,i$ produced; then complete the curve by an arc drawn from s with radius $s\,n$.

A fillet (from the French word *filet*, a band) is the small flat edging used to separate two larger mouldings, to strengthen their edges, or to form a cap or crowning to a moulding. The fillet is one of the smallest members used in cornices, architraves, bases, and pedestals. When placed against the flat

* *Apices*—plural of *apex*, the upper point of a triangle.

surface of a pedestal, it is usually joined to it by a small quarter-round hollow called the *Apophyge* (Fig. 124).

The torus, when worked very small, is called the *Astragal* (Fig. 125); but when worked so as not to project, as on the edge of boards to be joined, it is called a *bead*.

Figs. 126 to 133 are sections of *Gothic* mouldings. The whole of the construction lines are given in the illustration, and it is hoped the student will be able to work from these without any further aid. The whole subject of "Gothic Architecture" will be fully treated of in a separate series of lessons.

FREEHAND DRAWING FOR JOINERS.

We now proceed to give some examples of free-hand drawing, which we are sure will be acceptable to the student. In these examples Figs. 134 and 135 are studies of the wave-line. They are, in fact, the cyma recta repeated, the depth being lessened in Fig. 135.

Fig. 136 is a study of the elementary lines of a running scroll, formed of the wave-line, with the addition of spirals. Care must be taken in drawing these spirals, so that they may proceed from the stem in a smooth and continuous manner. They should start as a continuation of the wave-line so gradually, that if the stem beyond the spiral were removed, the scroll would be perfect, and that if the scroll were taken away the wave-line would remain uninjured. This should also be the case in Fig. 137, in which tendrils are added to the scrolls.

Fig. 138 is a further elaboration of the same design, the lines being doubled.

Fig. 139 is another simple running pattern based on the wave-line.

Figs. 140 and 141 are ancient borders worked on the ogee or cyma reversa moulding. These are both to be started in the same manner as Figs. 143 and 144—namely, by dividing the width into equal parts for the middle line of the arch or of the tongue, and dividing each space again to obtain the middle line of the dart or flower. The main forms are then to be sketched in.

Fig. 142 is the *Guilloche*, or chain, and is formed by concentric circles overlapping each other. This pattern is easily drawn with compasses, but is here given as a freehand study, in order to give the student an exercise in severity and accuracy of form.

Fig. 143 is a Greek border, composed of a leaf and dart, and is presented, of course, with the understanding that it is to be copied on a very much larger scale; and the student is again reminded that shading must be secondary to outline, and that therefore it is intended that each of the studies here given is to be drawn *twice*, first, as distinct practice in *outline;* and, secondly, another outline having been drawn, the shading may be added, but on no account is the shading to be begun until the outline can be drawn with facility. In commencing to draw this moulding, which is used as a decoration for the cyma reversa, set off the widths of the leaves, and draw perpendiculars, which will afterwards be the middle lines for the darts or tongues. Exactly in the middle of each of these spaces draw other perpendiculars for the midribs of the leaves. The curves are next to be drawn, being careful to balance the sides accurately.

Fig. 144 is the Greek ornament known as the *Egg and Tongue*. It is used as a decoration for the ovolo moulding. The method of commencing to draw this is the same as in the last example, and thus any further instructions are unnecessary.

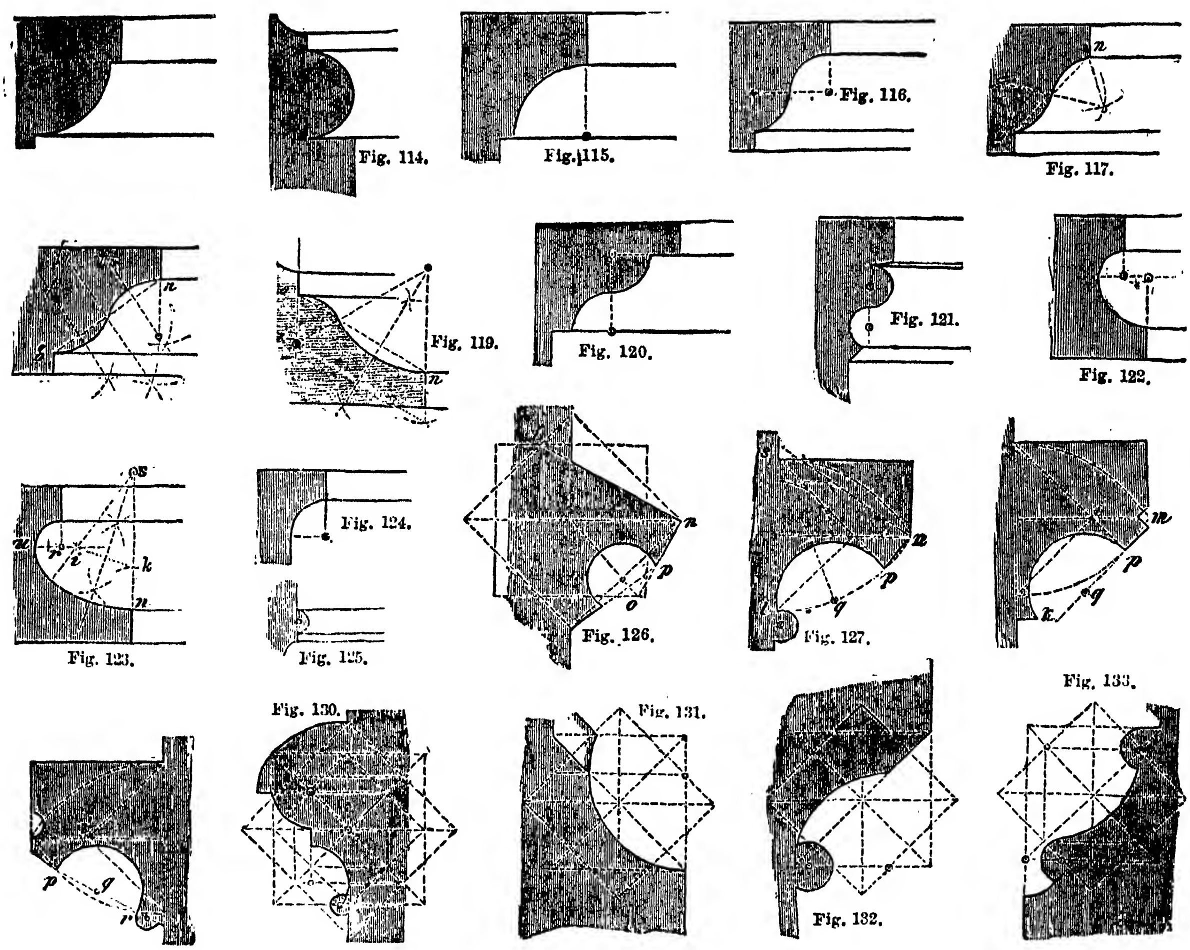


Fig. 114. Fig. 115. Fig. 116. Fig. 117. Fig. 119. Fig. 120. Fig. 121. Fig. 122. Fig. 123. Fig. 124. Fig. 125. Fig. 126. Fig. 127. Fig. 130. Fig. 131. Fig. 132. Fig. 133.

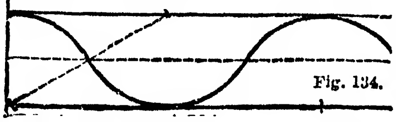


Fig. 134.

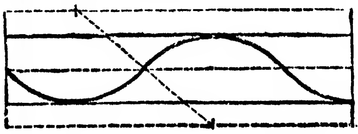


Fig. 135.

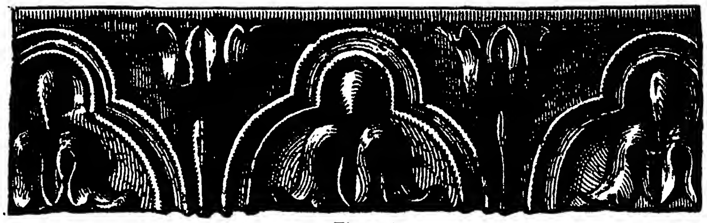


Fig. 140.

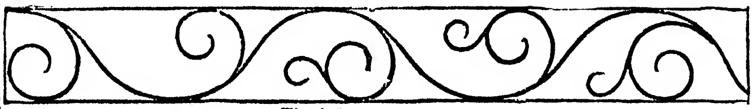


Fig. 136.

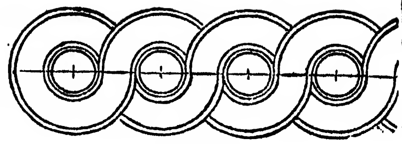


Fig. 142.

Fig. 137.

Fig. 138.

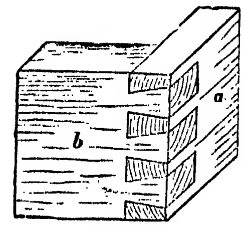


Fig. 109.

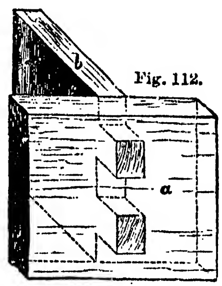


Fig. 112.

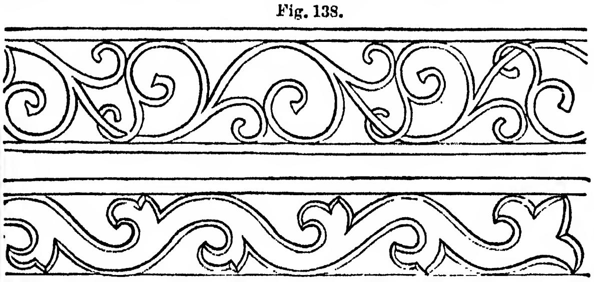


Fig. 139.

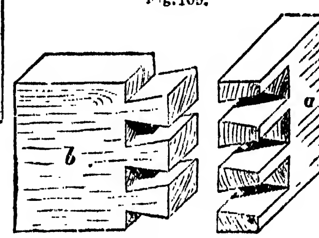


Fig. 108.

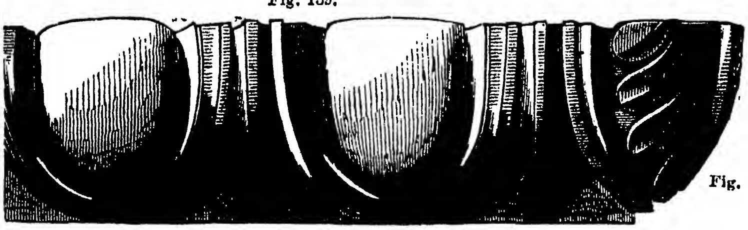


Fig. 144.

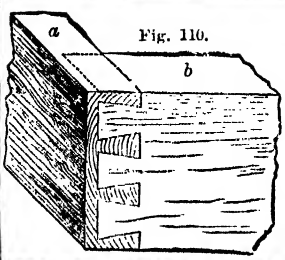
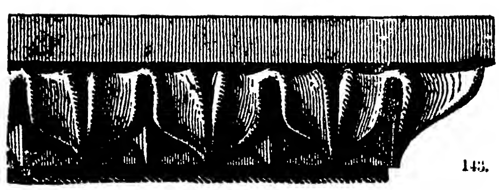


Fig. 110.



143.

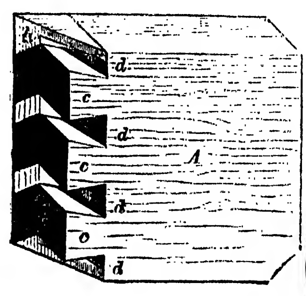


Fig. 111.

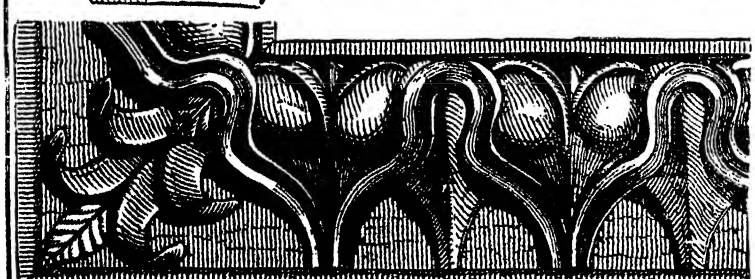
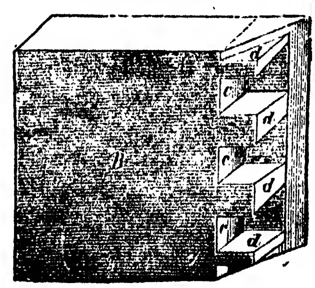


Fig. 141.



TECHNICAL EDUCATION AT HOME AND ABROAD.

V.—EDUCATION OF MASTERS (*continued*)—TECHNICAL INSTRUCTION IN ELEMENTARY SCHOOLS.

BY SIR PHILIP MAGNUS.

THE influence of technical education on Continental manufactures is shown not only in the chemical, but also in various branches of the engineering industries. Many of the engines produced abroad are in every respect equal to our own, and frequently much cheaper. Much of the machinery employed in mills and factories is home-made, and the beautifully light bridges that span some of the German rivers, combining, as they do, elegance of form with stability and economy of material, are models of construction, which could have been produced only by the application of advanced mathematical and scientific knowledge.

In the progress of the general manufactures of the country, the education of the master or mill-owner counts for much. Success depends greatly upon the ability of those who direct these industries to appreciate the applicability to their own work of any new invention or discovery, upon a knowledge of foreign countries, as well as of the habits and mode of living of the people whose custom the manufacturer is desirous of obtaining, and whose markets he endeavours to supply. A knowledge of modern languages is of the greatest advantage to manufacturers in enabling them to adopt improvements originated abroad, and to better identify themselves with the circumstances of foreign life. The substitution for classics of additional mathematics, and of two modern languages besides the mother-tongue, in most of the Continental schools in which men of trade and commerce receive their early education, is of great advantage to them, as supplying them with useful information, and as affording the best basis for the superstructure of higher technical instruction.

In describing foreign schools, and in considering the system of education pursued in them, we shall be struck by the careful and complete gradation of schools observable in some Continental countries, and the provision that is made for the education, in view of their special requirements, of all classes of the population. In the systematic arrangement and subordination of educational institutions, we have much to learn from the Germans and the Italians. In consequence of the frequent multiplication of schools of the same kind in this country, due mainly to the absence of any central authority that concerns itself with the entire system of education, many kinds of schools which are very much needed are altogether wanting, and it is difficult to say how the want is to be supplied. Of late years, efforts have been made to provide improved technical instruction, not only for artisans, but also for employers of labour; but in facilities for the higher education we are still far behind some of our Continental neighbours; and there can be no doubt that the maintenance of our present industrial and commercial position will depend, far more than is commonly supposed, upon the means that are provided for advanced technical education, and upon the extent to which those who have to direct great manufacturing works avail themselves of these opportunities.

TECHNICAL INSTRUCTION IN ELEMENTARY SCHOOLS.

In considering the opportunities for technical instruction which are offered to the British workman, one must not lose sight of the influence of primary education on his subsequent training. Abroad, the elements of ordinary education are so blended with what is commonly understood as technical instruction, that we invariably find both kinds of teaching pursued in the same school. In Great Britain, only very recently is the dependence of technical on primary education beginning to be fully recognised.

As the public elementary schools are essentially the schools for the people, and as we may assume that foremen in all kinds of works are generally chosen from among the workmen, we have to look to the education given in our primary schools for the commencement of the training of the workmen and foremen of this country. To what extent, then, it may be asked, is the future career of the workmen kept in view in the provisions that are made for their education in our public schools? In the teaching of reading, writing, and reckoning, every effort is made, and duly encouraged to give to the child of the British artisan a fair start in life. It is, indeed, sometimes said that our children are over-taught and subjected to undue pressure in order that their teachers may obtain their full share of remuneration, which, according to our present system, is mainly dependent upon their pupils' success. But a comparison of the hours of work in English and foreign schools would not show that the children of this country are more severely taxed than they are abroad; and although cases have occurred of weakly children having more work to do than their strength allows, the provisions of our Code are not by any means exacting, and do not demand from the average child more than a reasonable amount of work.

The only subjects of a technical character which are included in our present Code are certain branches of science and agriculture for children of both sexes, and needlework and domestic economy for girls. Drawing is taught in a relatively small number of schools, to rather less than a quarter of the number of children who are being educated in our public elementary schools. It is not, moreover, a subject included in the Code, being regarded as an extra, which is examined and inspected by other authorities, and by a different Department of State from that which superintends the instruction in other subjects. With the exception of needlework, which is obligatory in girls' schools, the curriculum of our ordinary elementary schools does not include any subject that can be correctly regarded as technical in character. By taking geography as a class subject, elementary science may be altogether excluded from the subjects of instruction; and in a very large proportion of the schools this option is made. Children in Standards V., VI., and VII. may be presented for examination in any two, but not in more than two of the so-called specific subjects. They are the following:—Algebra, Euclid and Mensuration, Mechanics, Chemistry, Physics, Animal Physiology, Botany, principles of Agriculture, Latin, French, Domestic Economy. Of these, all, except Latin, Animal Physiology, Botany, and perhaps French, may be regarded, if properly taught, as a part of the technical education of a child. In addition to reading, writing, and reckoning, the three essential requisites of primary education, drawing and elementary science, if practically taught, may be regarded as indispensable in the rudimentary technical education of our working classes. These subjects are not yet taught to the extent to which they should be. As I have already stated, drawing is taught in less than 25 per cent. of our schools, and there are many towns in England in which scarcely any of the children receive instruction in science. Indeed, in the statistics previously quoted, it must be taken into account that drawing is now taught in all schools under the London School Board, and consequently the proportion of children outside of the Metropolis who learn drawing is comparatively less than that already stated. In many places, particularly in the great centres of industry, commendable efforts are being made to introduce science teaching into our elementary schools. A great difficulty is the selection of suitable teachers. It is the methods rather than the results of science which are of so much value in the education of children. The information conveyed by science lessons is useful in itself; but unless such lessons are made the means of awakening the intelligence, of stimulating the observing faculties, and of developing the reasoning powers, they fall short of their main purpose. Other subjects can be taught with sufficient success by the ordinary teacher; but science, even in its elementary stages, requires to be taught by one who has a wide grasp of his subject, and can utilise his lesson not only for imparting information, but for drawing out and developing the innate faculties of the child. To attempt to attach a teacher so qualified to every elementary school is clearly impossible, both on account of the scarcity of such teachers and of the costliness of the instruction. It would prove, moreover, a most uneconomical arrangement, seeing that only a few children in each school would be able to take advantage of the instruction.

In Birmingham and Liverpool a very successful attempt has been made to overcome the difficulty by appointing a teacher of high attainments, with a full knowledge of his subject, and skilled in the methods of instruction, to go round from school to school, and to give science lectures to the children and to their teachers. This peripatetic philosopher carries his apparatus with him, and visits in turn all the chief schools of the town.

The system has been described by Mr. W. Lant Carpenter in a paper read before the School of Arts, from which I quote the following extracts :—

"The special feature of the scheme, and one which is rightly regarded as of the very highest importance in connection with it, is that these science demonstrations are given not by the ordinary staff of the school, but by a specially appointed expert, whose sole duty it is to go round from school to school, giving practically the same lesson in each one, until all have been visited. The apparatus necessary is kept, and the experiments are prepared, at a central laboratory at one of the schools, and whatever is needed for a given lesson is carefully packed in neatly partitioned boxes, and is taken from school to school in a hand-cart, drawn by a boy employed for the purpose. In this way the Birmingham demonstrator, Mr. W. Jerome Harrison, F.G.S., is able to give four lessons per day, of about forty-five minutes each, in as many different schools; and at present all the thirty Board schools, or sixty departments, are thus receiving such instruction, which is given to about 2,800 boys and 1,600 girls, from among the 17,944 who were presented for examination in 1883."

In the eighteen Board schools of Liverpool in 1883, 10,512 children were presented for examination, 7,203 of these were examined in some of the class subjects; moreover, every boy in Standards IV. to VI. was examined in mechanics, and every girl in the same standards in domestic economy, the numbers being 1,868 boys and 1,334 girls.

"In Birmingham the lessons are given fortnightly. One of the regular staff of the school is always present, and it is his duty in the intervening week to go over the lesson again to the class, and drive it home. After this, each child writes out notes of the lesson, often in reply to questions set, and these notes are revised by the demonstrator himself, before he next visits the school. The practice of having one or more of the ordinary teachers present at the demonstration is fraught with more important consequences than at first sight appears.

"The general scheme of instruction is as follows :—

"*Boys. First Stage.*—Matter in three states, solids, liquids, and gases. Mechanical properties peculiar to each state. Matter is porous, compressible, elastic. Measurement as practised by mechanics. Production of a plane surface. Measures of length, time, and velocity.

"In Birmingham this is given in twenty-one lessons, in Liverpool in thirty-four. Both courses include such practical subjects as the spirit-level, air-pump, thermometer, clocks, hydrometers, filters, &c.

"*Boys. Second Stage.*—The meaning of force, and work done; gravitation and the three laws of motion; the idea of energy, both kinetic and potential, and of its conservation.

"*Boys. Third Stage.*—The principles of the six simple mechanical powers, the hydrostatic press, and the parallelograms of forces and velocities.

"As arranged for the girls, the instruction in the so-called 'domestic economy' is as follows :—

"*Girls. First Stage.*—Functions of food, and its distribution by the blood; the chemistry of oxygen, hydrogen, carbon, and nitrogen; the proximate composition of various kinds of food; clothing and its uses, and the mechanics and chemistry of washing, both as regards the person and the clothes.

"*Girls. Second Stage.*—Food, its functions and composition, treated more in detail than in the first stage; and the physical and chemical principles involved in warming, cleaning, and ventilating a dwelling.

"*Girls. Third Stage.*—Rules for health; the management of a sick room; the preparation and culinary treatment of food; and lessons on expenditure and savings.

"As regards the expense of the scheme, the cost to the Liverpool School Board was about £100 for the stock of apparatus, and £470 yearly for the instructor and his assistants. In Birmingham, more than £200 has been spent upon apparatus, and the present annual expenditure is—chief demonstrator, £300; two assistants, £255; two juniors, 10s. and 12s. per week, say £55; or a total of £610, or about £10 per year per school department. It is obvious that, under this plan, a maximum of highly efficient teaching is obtained at a minimum of cost; since the same demonstrators and the same apparatus are available for a large number of schools—in Birmingham, at present, for sixty school departments."

ANIMAL COMMERCIAL PRODUCTS.—I

PRODUCTS OF THE CLASS AVES.

Birds are warm-blooded, vertebrated animals, characterised by a double circulation and respiration, the adaptation of their anterior extremities for flight, oviparous reproduction, and a covering of feathers. The following classification, founded on certain modifications in the structure of the beak and foot, may be accepted as a useful arrangement for popular purposes.

1. *Raptores* (Latin, *raptor*, a robber), or birds of prey, having a strong, curved, sharp-pointed beak, short robust legs, and a foot furnished with three toes before and one behind, which are armed with long, strong, crooked, and more or less retractile talons, adapted to seize and lacerate a living prey. Examples: eagle, hawk, and vulture.

2. *Insessores* (Latin, *insideo*, I sit on), or perching birds, having three toes before and one behind, slender and flexible, with claws, long, pointed, and slightly curved; a foot, in fact, organised and adapted for the delicate operations of nest-building, grasping the slender branches of trees, and perching on them. Examples: sparrow, robin, and crow.

3. *Scansores* (Latin, *scando*, I climb), or climbing birds, with the four toes arranged in pairs, two before and two behind—a conformation of the foot most suitable for climbing trees. Examples: woodpecker, cuckoo, and parrot.

4. *Columbidæ* (Latin, *columba*, a pigeon), including pigeons and doves.

5. *Rasores* (Latin, *rado*, I scratch), or scratching birds, having three toes before and one behind, strong, straight, and terminated by robust, obtuse claws, adapted for scratching up the soil. Examples: turkey, pheasant, partridge, and the common barn-door fowl.

6. *Cursores* (Latin, *curro*, I run), or running birds, with wings unfitted for flight, and feet formed for running swiftly over the ground, with two and sometimes three toes in front, and none behind, except in the apteryx. Examples: ostrich and cassowary.

7. *Grallatores* (Latin, *grallator*, a stalker), wading birds with long legs, the three anterior toes long and slender, and the posterior toe elevated and short—a form of foot and leg which enables the bird to seek its food in water along the margins of rivers, lakes, and seas. Examples: crane, heron, sandpiper.

8. *Natatores* (Latin, *natator*, a swimmer), swimming birds, including those which have the toes united by an intervening membrane. The body is protected by a dense covering of feathers, and a thick down next the skin; the whole organisation is adapted for aquatic life. Examples: duck, swan, and goose.

The products of the class Aves consist of

FOOD.

All these orders of birds, with the exception of the first, afford flesh which may be eaten. The eggs of many of them are very nutritious, especially those of the Rasorial birds: 1,035,171,360 were imported into Britain in 1886. In one case, even the nest is available as food—namely, the Chinese edible birds' nests, constructed by a Javanese swallow. The collecting of these nests employs numbers of people, as they are largely exported to China from Java, Ceylon, and New Guinea. It is calculated that 30,000 tons of shipping are engaged in this traffic, and that the value of their freights is above £280,000. But the chief commercial value of birds lies in their

FEATHERS.

A feather consists of three parts—the quill, the shaft, and the vane. The quill is that part of the feather by which it is attached to the skin; it is cylindrical, hollow, and semi-transparent, possessing in an eminent degree the qualities of lightness and strength. The shaft is covered by an outer layer of firm, horny material, like that which forms the quill, and encloses a soft elastic substance called the pith. The vane consists of barbs and barbules. The barbs are attached to the sides of the shaft, the barbules are given off from either side of the barb, and when long and loose they characterise the form of feather known as a "plume"—*e.g.*, that of the ostrich, which, commercially considered, is the most valuable of feathers. The development of feathers is always preceded by that of down, which constitutes the first covering of young birds. Their colours are due to peculiar organic pigments, which may

be separated by appropriate solvents. The beautiful play of colours shown by some feathers is referable to a decomposition of light, analogous to that produced by mother-of-pearl, and other striated surfaces.

The preparation of feathers for military decoration, or for the toilette, forms the art of the plumassier, the French term for the artisan who works on them. Feathers may be dyed a variety of beautiful colours, and of these, rose-colour or pink is given by safflower and lemon-juice, and deep red by a bath of Brazil wood boiling hot, after aluming; indigo supplies the blues of every shade, and turmeric the yellows, alum being the usual mordant.

Ornamental Feathers.—The most valuable and esteemed ornamental feathers are, unquestionably, those of

The Ostrich (*Struthio camelus*).—The elegance of these feathers arises from their slender stems and disunited barbs. Those taken from the living or from recently killed birds are far more beautiful than the cast or dropped ones. The feathers from the back and above the wings are the best; next, those of the wings and tail. Ostrich feathers dyed black—for which purpose logwood, copperas, and acetate of iron are used—are sold to undertakers as mourning plumes; a full set is worth from £200 to £300. Ostrich feathers are scoured with soap, and then bleached. Fine white ones are worth from seven to eight guineas a pound. The finest white feathers of this bird, which is indigenous to Northern and Central Africa and Arabia, come from Aleppo in Syria. Good ostrich feathers are also received from Algiers, Tunis, Alexandria, and Cairo, and inferior ones from Senegal and the island of Madagascar.

The *Little Egret* (*Herodias leuce*) is found in all the countries on the Mediterranean coast, and in Asia as far as the East Indies; an allied species, *H. œgretta*, is a native of tropical America. The feathers of both species are of the purest white, very delicately formed, six or eight inches in length, with slender shafts. The Turks and Persians embellish their turbans with them, and they form plumes for ladies' head-dresses in Great Britain and on the Continent.

The *Great White Heron* (*Ardea alba*) inhabits the shores of the Caspian, the Black Sea, and lakes of Tartary, and is also found in America and Africa. The largest and most expensive white heron feathers are furnished by the plumage of this bird.

Common Heron (*Ardea cinerea*).—The black heron feathers are supplied by this species, which is found throughout Europe, but especially in Prussia, Poland, and Russia. We receive the greatest quantity from Siberia.

Adjutant (*Leptoptilis argála*), and a kindred species (*L. marabou*), furnish the exquisitely fine and flowing plumes termed "Marabou feathers." The former species is the well-known scavenger bird of India, its name being derived from its habit of frequenting the parade-grounds; the latter is a native of Africa.

It is impossible to enumerate all the birds whose beautiful plumage supplies us with ornamental feathers. The feathers of the Bird of Paradise, the gold and silver pheasants, the peacock, the several species of *Ibises*, the flamingo, the beautiful wing and tail feathers of the Argus pheasant, and the wing of the partridge and ptarmigan are all worn in children's and ladies' hats. Cocks' feathers furnish plumes for soldiers; eagles' feathers are worn in the hat and bonnet in Scotland, and a plume of them is a mark of distinction amongst the Zulus in South Africa. The wing and side feathers of the turkey supply trimmings for articles of ladies' apparel, and are made into victorines, boas, and muffs.

Artificial flowers made from feathers are now much worn by ladies. The feathers selected for their manufacture are chiefly those of a purple, copper, or crimson colour, from the breasts and heads of humming-birds.

Feathers are also worn as articles of clothing. The skin of the swan, after being properly prepared, is used for muffs, linings, and a variety of other articles of dress; the skin and feathers of the penguin, puffin, and grebe (*Podiceps cristatus*) are worn as clothing on account of their beauty and warmth, supplying suitable material for victorines, tippets, boas, cuffs, and muffs, and other articles of winter attire. The native inhabitants of the Arctic regions, in some parts, make themselves coats of bird-skins, which are worn with the feathers inside. Confucius, the Chinese philosopher, writes, that ere the art of weaving silk and hemp was understood, mankind used to clothe themselves with the skins of beasts and with feathers; and it is very certain that the Chinese are now very skilful and ingenious in the art of plumagery or feather-working. They manufacture garlands, chaplets, frontals, tiaras, and crowns of very thin copper, on which purple and blue feathers are placed with much taste and skill.

PROJECTION.—IX.

PENETRATIONS OF SOLIDS (*continued*).

FIG. 105 is the plan and elevation of a square prism, penetrated at its *edges* by a smaller prism, their axes being at right angles to each other. Having drawn the square A B C D—the plan of the larger prism—draw the line E F through the centre, and make it equal to the required length of the smaller prism. At F draw J K, and at E draw G H, equal to the diagonal. On G H construct half the square of the end—viz., produce F E until E I equals E H, and join I H and I G. Draw H J and G K. These will complete the plan of the smaller prism, which will penetrate the sides of the plan of the larger prism in L M N O. Project the elevation C A D of the larger prism from the plan, and draw G′ K′ at right angles to the axis. On each side of G K set off the length E I—viz., points E, E; F, F. Draw perpendiculars from L and M, cutting G′ K′ in L′ M′. Join C L′ C, D M′ D, which will be the lines marking the intersections of the two prisms.

Fig. 106 shows the projection of this object when the axis of the smaller prism is at an angle to the vertical plane.

Fig. 107 is the development of the longer prism, showing the shape of the openings through which the smaller prism is to pass. On a straight line set off four times the width of the side of the plan represented by A D B C A. Erect perpendiculars from these points equal to the height of the prism, and draw a horizontal line at their extremities. Produce E F, G′ K′, and E F, to cut line C in P Q R, and line D in P′ Q′ R′. On each side of Q set off Q S and Q T, equal to C L in the plan, and set off the same measurement—viz., Q′ S′ and Q′ T′—on each side of Q′. Join P S R T, and also P′ S′ R′ T, and two lozenge-shaped figures will be formed. It will be observed that these are wider across than the prism which is to pass through the aperture, but it must be remembered that the two sides of the larger prism are bent at right angles to each other, and thus, when the perpendiculars A and B are brought together, S and T approach each other until the distance between them is equal to M N in the plan, which, it will be seen, corresponds with the diagonal of the end of the smaller prism.

Fig. 108 is the development of one of the projecting ends of the smaller prism. Here the widths are taken from G I in the plan of the smaller prism (Fig. 105), and the heights from D F, J N, M K.

PLAN AND ELEVATION OF A CYLINDER PENETRATED BY A SMALLER ONE.

The circle in the lower plane (Fig. 109) represents the plan of the larger, and the parallelogram D D′ E′ E that of the smaller cylinder. From this figure project the mere cross which forms the elevation. No explanation of this process is deemed necessary, the object of the lesson being to find the curve generated at the points where the penetration takes place. The student is here reminded that, as the plan is the view of the object when *looking down* upon it, the line C A B C′, which is the top line of the smaller cylinder in the elevation, is the *middle* line in the plan; and thus the line D E, which is the front or most prominent line of the cylinder in the plan, is represented by D E, the middle line in the elevation.

From C′ in the plan, with radius C′ E, describe a semicircle, which represents half of the plane of the end of the cylinder. This plane, although laid down flat, is supposed to stand upright on the line E E′ at right angles to the plan. Divide the semicircle into any number of equal parts, and from these divisions draw lines meeting E E′ at right angles in F and G. Set off the lengths of these perpendiculars on each side of the line D E in the elevation—viz., F F and G G, and draw lines from these points across the whole length of the elevation of the smaller cylinder. Draw similar lines parallel to C C′ from the corresponding points in the plan—viz., F F′, G G′, which lines will be seen to pass, not only through the smaller, but

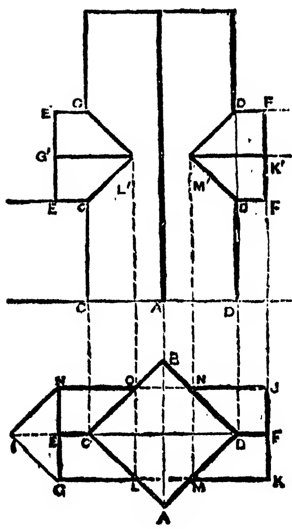


Fig. 105.

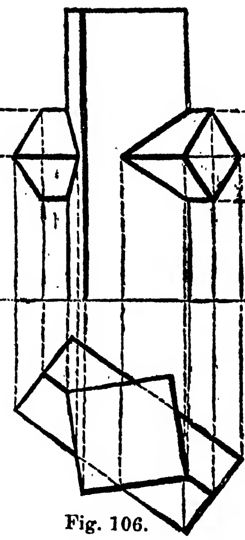


Fig. 106.

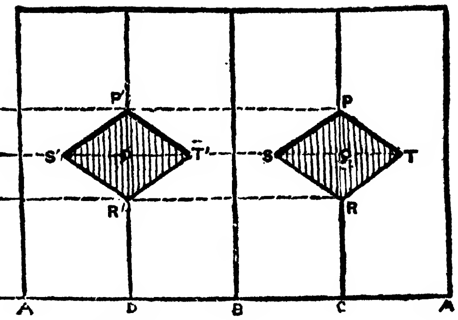


Fig. 107.

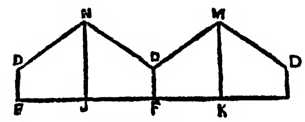
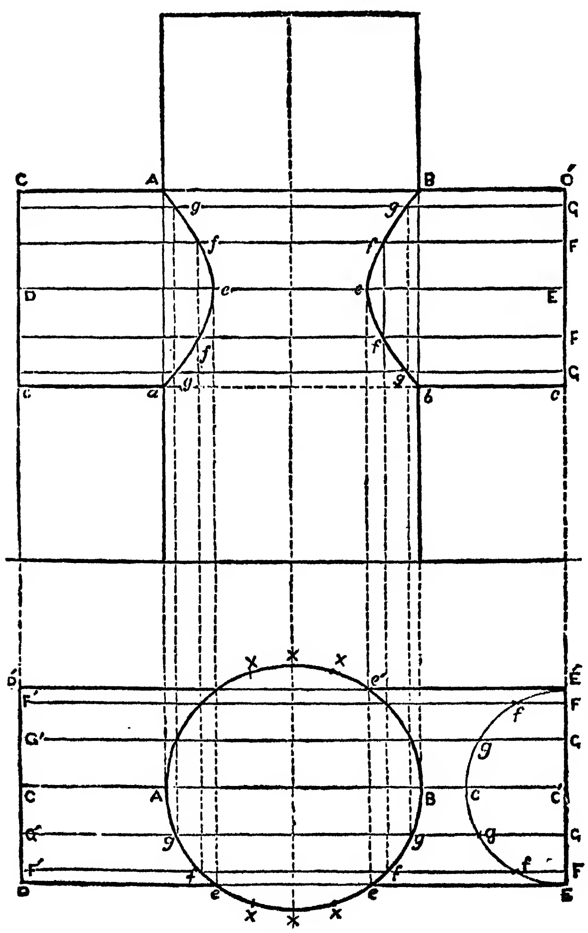


Fig. 108.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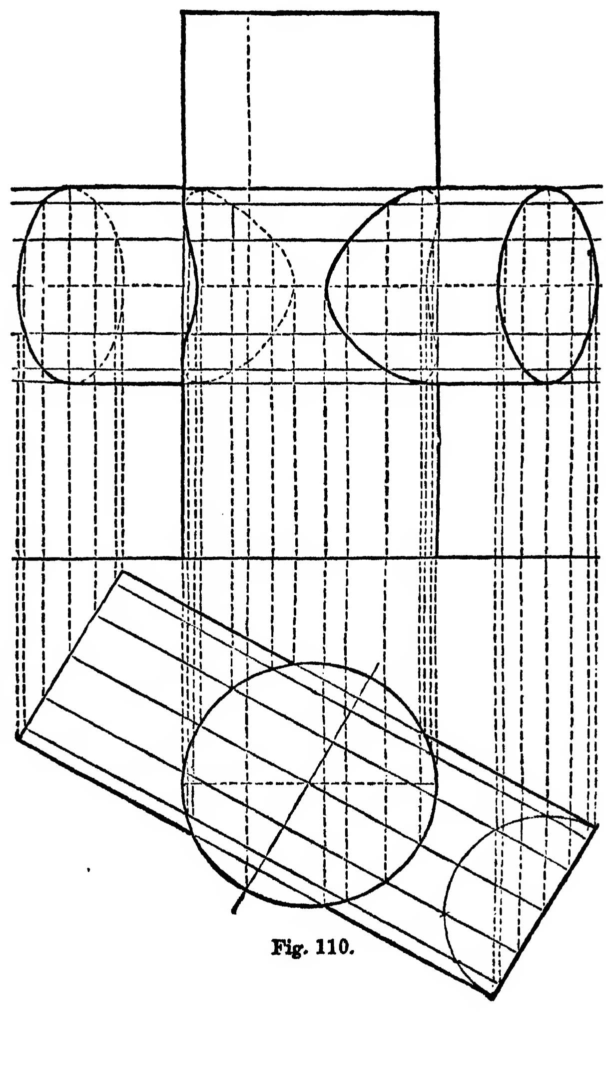


Fig. 110.

also through the larger cylinder, representing as they do planes common to both the solids. From the points A and B, $f\ g\ e$, draw perpendiculars to meet the horizontals drawn from the points similarly lettered in the elevation, and the intersections $e\ e$, $f\ f$, $g\ g$ will give the points through which the curves of the penetrations are to be drawn.*

Fig. 110 shows the projection of the objects when the plan has been rotated, so that the axis of the smaller cylinder is at an angle to the vertical plane. The lettering is omitted, but as all the lines of construction are shown, it is hoped that the student will be able to project the object with the aid of the instructions here given. It has repeatedly been shown that when an object is simply rotated on its axis, or on a solid angle, without altering the inclination, the *heights* of the various points will remain the same. This fact may be observed in a crane. When the weight has been raised as high as may be required, the crane is rotated, but the height of the top and of the weight will be exactly the same in which direction soever the crane may be turned, and thus the piece of ground overhung by the crane and weight will remain *the same in form though altered in position.* If, therefore, the plan and elevation given in Fig. 109 has been prepared, it will only be necessary to repeat the plan, placing the axis of the smaller cylinder at the required angle; then perpendiculars raised from the various points in the plan may be intersected by horizontals drawn from the corresponding points in the elevation, and the intersections thus obtained will give the points required for the projection.

But, in practice, the whole of the object shown in Fig. 110 might be projected without referring to the previous one, and it is important that the student should understand this, as otherwise time would be lost. To project the object when at any angle, therefore, proceed in the following manner :—Draw the circle which represents the plan of the larger cylinder. Draw a line through the centre of this, making an angle with the intersecting line corresponding to the angle which the axis of the smaller cylinder is to make with the vertical plane. On this line set off, on each side of the centre, half the length of the smaller cylinder, and at these points draw lines at right angles to the line of the axis. The plan of the object will then be complete, and we proceed to project the elevation from it. Draw a fine or dotted line through the centre parallel to the vertical plane, and from the extremities of this diameter carry up the perpendiculars which are to form the edges of the elevation of the larger cylinder. Now it must be borne in mind that these are *not the points from which the elevation of the cylinder would be projected if the axis of the smaller one were parallel to the vertical plane.* In that case the perpendiculars would be raised from the points where the axis of the smaller cylinder cuts the circumference of the plan of the larger one; but if this were done in the present position of the plan, the elevation would be *narrower* than the cylinder. All vertical sections of a cylinder are parallelograms, and all those which pass through the centre are equal. Still, reference to Fig. 8 (page 9) will remind the student that the real size of a plane is only obtained in the elevation when it is parallel to the vertical plane; and it will be seen that the elevation of the plane, of which the diameter of the plan, which is *at an angle* with the vertical plane, is the elevation, would not therefore be the projection of the largest section, and would not represent the true width any more than the elevation of the open door in Fig. 11 (page 24) represents its real width, and it thus becomes necessary to draw the dotted line referred to, so that the elevation may represent the *greatest* width of the cylinder. Now draw another diameter in the plan at right angles to the axis of the smaller cylinder, and the extremities of this line will be the front and back lines of the larger cylinder, which, if the axis of the smaller one were parallel to the vertical plane, would be the centre of the elevation; but as it has of course rotated with the object, it is central no longer, but its relation to the heights remains the same, however the larger cylinder may be turned on its axis.

On this perpendicular, therefore, set off from the intersecting line the real height, and draw the horizontal line, which represents the top of the larger cylinder.

Mark on the perpendicular, too, the height at which the axis of the smaller cylinder intersects that of the larger, and draw a horizontal through the point.

Returning now to the plan, the preparation for the projection of the circular end of the smaller cylinder, as shown in Fig. 77, is necessary. On the line which forms the end in the plan draw a semicircle, and divide it into any number of equal parts. Through these points of division draw lines parallel to the axis of the smaller cylinder, which will be seen to pass through the plan of the larger one, and the intersections will be the plans of points "common to both" cylinders.

Now, from the points where these lines meet the straight line, which is the plan of the end of the smaller cylinder (on which the semicircle has been drawn), raise perpendiculars passing through the horizontal line which has been drawn across the elevation, and above and below this horizontal set off on the perpendiculars the *lengths of the lines drawn from the points in the plan from which they started* to the semicircle. Join the points thus obtained, and the projection of the end will be obtained. From each of the points through which the ellipse has been drawn now draw horizontal lines, and raise perpendiculars from the points in the opposite end of the plan; the curve of the end of the smaller cylinder which is turned away must then be traced through these points, and it will be observed that, as only one side of the ellipse could really be seen in this position of the object, the other half is drawn in dots. It now remains to find the shape of the curve of penetration—that is, the curve generated where the smaller cylinder penetrates the larger, and this will be accomplished by finding the elevations of the points which in the plan were spoken of as "common to both" cylinders. From these points —that is, from the points where the lines drawn parallel to the axis of the smaller cylinder cut the circle, which is the plan of the larger one—erect perpendiculars cutting the horizontal lines in the elevation, which are in fact the elevations of the lines in the plan. The curves must then be traced through the intersections of these two sets of lines. The perpendiculars must be drawn not only from the points on the front of the plan, but from those on the back part, and these cutting the horizontals will give the points through which the curve on the other side of the cylinder is to be drawn.

The reason why the perpendiculars at the back are to cut the same horizontals as those in the front, is that already pointed out—viz., that a point is not altered in height when the object on which it exists rotates on its axis in the manner shown in the diagram.

* The points x, x, x are not used in this projection, but will be subsequently referred to.

APPLIED MECHANICS.—IV.

BY SIR ROBERT STAWELL BALL, LL.D.,
Astronomer-Royal for Ireland.

THE CRANE.

INTRODUCTORY—THE FRAMEWORK—THE WHEELWORK.

In the various operations connected with manufactures, and with the transport of goods from one place to another, it frequently becomes necessary to raise weights and carry them about. When the weights are large, amounting as they often do to many tons, special mechanical appliances have to be used. It is our intention in this lesson to examine into some of the machines used for this purpose.

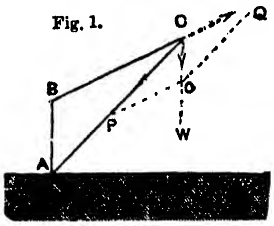
In unloading a ship at the quay-side, some heavy weight—such, for example, as a block of marble weighing ten tons—must first of all be lifted from the hold. It must then be carried from the ship to the quay, and there be deposited in safety. The machine which is able to accomplish this must have three distinct properties. In the first place, it must be a sufficient mechanical power to overcome the resistance. In the next place, it must be sufficiently strong to sustain the load suspended from it; and in the third place, it must be capable of moving the block, when suspended, from the ship to the quay. These three requisites are very beautifully combined in the useful machine known as the *lifting crane.* With its powerful aid three men would be easily able, at the cost of a little time, to unload the block of marble, even though it weighed ten tons. We shall consider the several parts of a crane separately, and show how each is adapted for the work it has to perform; we shall then describe some forms of crane which are used for various purposes in the arts of construction.

THE FRAMEWORK.

The form of crane which is most familiarly known is that which is sometimes called the *jib-crane*. It is in reality a triangle, one side of which is held vertically, while the load is suspended from the opposite vertex. The framework of this crane—with which alone we are at present engaged—is represented in Fig. 1 in a diagrammatic manner. A B C is a triangle of which the side A B is held constantly vertical, while the load is suspended from the vertex C.

We shall first endeavour to ascertain the nature and amount of the strains along the different parts of this structure. A knowledge of these strains is quite essential to a complete understanding of any machine. By this inquiry the proportions of the different parts can be properly adjusted, so that failure of strength on the one hand, or, what is also very undesirable, extravagant waste of material on the other, may be equally avoided.

Fig. 1.



In Fig. 1, W is the position of the suspended weight. If I take a length, C O, which is proportional to the magnitude of W, and place an arrow to indicate the direction of the force, the line C O represents the force, as explained in the first lesson in "Mechanics" (POPULAR EDUCATOR, Vol. III., p. 12). Now this force C O must be supported by B C and A C, and therefore there must be certain strains acting down these lines. In order to find them, draw O P parallel to B C, and O Q parallel to A C. Then by Lesson III. ("Mechanics") the force O C can be decomposed into two forces, C P and C Q. The directions of these forces are indicated by the arrows: that along C A is a force of compression, that along C B is a force of extension. Since O C and O P are parallel to A B and C B, the triangle C O P is similar to the triangle A B C, and hence the forces O C, C P, and C Q are proportional to the sides of the triangle A B C. If, therefore, the load be represented by A B, the strains along B C and A C are represented by their lengths.

The line B C is in a state of tension; that is, the force is tending to tear it asunder. Now a force of this kind is called in mechanics a "tie," and the amount of the force which is straining is called its tension. On the scale of the figure the line B C is double A B, and hence the tension of B C must be double the load. If, then, the crane were employed in raising a load of ten tons, the tension along B C would be twenty tons, and the tie must therefore be strong enough to bear this amount. But in constructions of this kind it is not sufficient that a piece be just sufficiently strong to bear the strain it has to carry: we must always allow a very considerable margin. This is especially true in a machine like a crane, which is subject to countless jerks and shocks, which for a moment place a far greater strain upon its parts than would be produced by the mere load it supports. In the lowering of heavy weights this is especially the case, for sometimes slight slips occur in the links of the chain, or the load has to be stopped suddenly in its descent. Hence we are accustomed in mechanical construction to introduce what is called the "factor of safety." Thus, in the present case, instead of making the tie just strong enough to bear the utmost load the crane is intended to raise, we make it ten times as strong: the factor of safety is then said to be 10. In a crane the factor of safety should not be less than 10. It is sometimes even more than this; but in other machines which are not exposed to the rough usage to which cranes are liable, the factor need not be so large.

Wrought iron, from its great tenacity, is admirably adapted for making the ties of cranes. A rod of iron one square inch in section will require a force of nearly twenty tons to tear it asunder. Hence we must make a crane on the proportion of Fig. 1 with a wrought-iron tie ten square inches in section, as it will then be able to withstand any strain less than 200 tons—that is, it will be ten times as strong as would be absolutely required for the bare purpose of sustaining the weight. In every case the tie, if made of wrought iron, should have a total section in no place less than half an inch for each ton of strain.

The jib A C has to withstand a thrust. In fact, it is a pillar, and the component of the load which it supports is tending to crush it. It must therefore be made of materials which are capable of resisting a crushing force. In ordinary cranes it is very often made of a piece of timber, which is very well adapted for resisting a crushing force. A bar of wrought iron, such as would make an admirable tie, would be quite unequal to withstand the crushing without being of great size and cost. Sometimes both jib and tie are cast in one piece of cast iron. This arrangement answers well for cranes which are used for raising a few tons, but would be quite unfit for the largest cranes, on account of the massiveness which would be necessary to give sufficient strength. By far the best arrangement for the jib of a large crane is a girder of riveted wrought iron; for by means of this arrangement the material is so disposed as to present a large amount of resistance to a force of crushing.

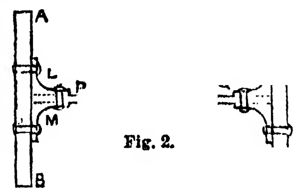


Fig. 2.

The form which a wrought-iron jib may have will be understood from the section shown in Fig. 2. A B, C D are iron plates, which are riveted together in lengths. A good plan of fastening these plates together is shown in Fig. 3, where the plates overlap, and are riveted together, the object of the arrangement being to have the united pieces just as strong at the joint as elsewhere. Two plates the whole length of the jib are thus prepared, and they are shown in section in A B, C D of Fig. 2. Now these plates being thin in proportion to their length, would not be stiff unless secured together. They are perhaps one inch thick by about ten inches wide, and as they may be fifteen feet long, they are in reality only strips or ribbons. They are then bound together by plates of iron, of which the section is shown at P Q. These plates of iron are attached to the plates at right angles by means of what are called angle-irons, shown at L and M. These angle-irons are riveted to both, and so the whole is bound into one piece. The process of riveting is admirably adapted for this purpose, as the rivet in cooling exerts a tremendous force in drawing the pieces together.

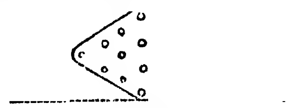
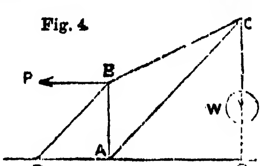


Fig. 3.

A jib made in this way is light, and at the same time extremely strong. In fact, it is hard to see how such a jib could be crushed unless the rivets were actually torn across; and they are made strong enough to prevent this from being likely to happen. The thrust which the jib has to support is generally at least three or four times as great as the load which the crane supports. This is evident from the fact that the three forces are proportional to the sides of the triangle A B C; so that these precautions are not unnecessary.

We have, then, examined briefly into the structure of the jib and the tie. We now come to consider the part A B (Fig. 1) by which they are supported. The post has another important duty to fulfil—it supplies the pivot about which the crane turns. This is often made of cast iron, and is firmly embedded in solid masonry. The post requires to be very stout, as there is a great strain upon it tending to snap it off at A. The magnitude of this strain may easily be understood when we remember the principle of moments, which has already been laid down in Lesson VIII. in "Mechanics." If W be the magnitude of the load, and A Q (Fig. 4) be the length of the perpendicular from A in the direction of W, then W × A Q is the moment with which the weight tends to wrench off the post A B; but the moment W × A Q is equivalent to—

Fig. 4.



$$\frac{W \times AQ}{AB} \times AB;$$

and hence the force tending to break the post is equivalent to a force—

$$\frac{W \times AQ}{AB}$$

acting at a distance A B. This is in general larger than W.

If we suppose A B not to be firmly embedded in the ground, we must by some other means exert a force upon it sufficient to counteract the moment of the weight. There are two different ways in which this may be accomplished.

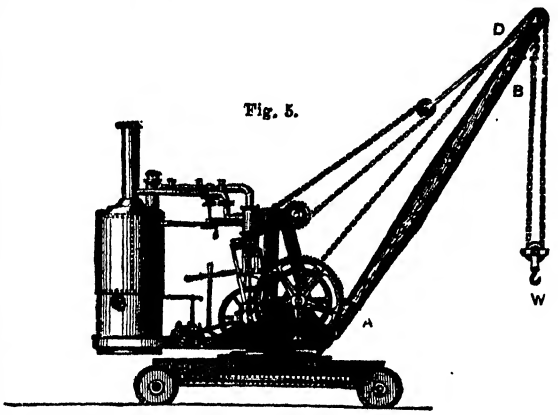
In a crane which is often used for quarrying and other rough purposes, and which is sometimes called a *guy crane*, there are two stays, one of which, B D, is shown in Fig. 4. These stays are attached at one end to the top of the post, while the other end is firmly secured into the ground. By this means the post is supported without being itself of great strength or embedded very deeply. The disadvantage of this form is that the crane takes up a great deal of room, and also that it is only able to turn round a part of an entire circle, as the jib comes in contact with the stays in the extreme positions.

Another method by which a crane-post can be supported is by having a counterpoise on the other side, which counteracts the effect of the load. This arrangement is particularly convenient for portable cranes, when it is impossible to secure the post in the ground, or even to be able to fasten the ends of the stays of a guy crane.

A very convenient portable crane on this principle is shown in Fig. 5. Here the boiler and fireplace of the engine which works the crane project behind, and their weight acts as a counterpoise to whatever load may be suspended from the hook W.

This crane is adapted to run upon a tramway, and is thus very convenient in all operations connected with the transport of heavy materials. The tie is in this case partly composed of a wrought-iron rod and partly of a chain, which passes through a pulley at D. The object of this arrangement is to enable the jib to be raised or lowered as the exigencies of the work may require. This chain is not to be confounded with the lifting chain, which will be presently considered. The jib, A B, in this crane is formed of timber. It will be seen that it is to some extent spindle-shaped. The reason of this is that the jib is more liable to break in the middle than at either end, so that by giving to it this form it is made of an equal strength throughout.

Fig. 5.



THE WHEELWORK.

The hoisting apparatus is entirely distinct from the framework which we have been considering. It consists of a barrel or drum, on which the chain is wound, and a train of wheels, through the intervention of which the barrel is turned by a handle. The nature of the train of wheels depends upon the load which the crane is intended to raise and the power which is employed.

In order to explain this, we shall take a simple case first. Suppose we have a pinion of 20 teeth mounted upon a shaft, and that this shaft is turned by a handle which moves in a circle of three feet in diameter. Now let this pinion turn a wheel of 200 teeth, and on the same shaft as the wheel let a drum one foot in diameter be secured. Now supposing this arrangement be applied to a crane, and that the chain pass over the pulley at the top of the jib, and have a weight suspended from it, what weight will one man turning the handle be able to raise?

The principle of virtual velocities will determine this. We must first ascertain the space through which the power of the man must be applied in order to raise the load a given distance. When the barrel has made one revolution, $\frac{22}{7} \times 1 = \frac{22}{7}$ feet of chain will be pulled in. But when the barrel has made one revolution, the wheel of 200 teeth must also have made one revolution. But the pinion which gears into this wheel must have made ten revolutions, because the wheel has ten times the number of teeth in the pinion. The handle must therefore have been turned round ten times. Now the handle describes a circle three feet in diameter, and therefore the distance through which the power of the man must be exerted is $3 \times \frac{22}{7}$ for one revolution; and therefore $30 \times \frac{22}{7}$ for ten revolutions.

Thus the virtual velocities of the power and the load are $\frac{22}{7}$ and $30 \times \frac{22}{7}$. But by the principle of virtual velocities already referred to in the "Lessons in Mechanics," the mechanical efficiency of the machine is the ratio of the virtual velocities, that is—

$$30 \times \frac{22}{7}$$

$$30.$$

Hence the efficiency of this crane is thirtyfold—that is, for example, if a man exerted a pressure of 40 lb. on the extremity of the winch, he would be able to raise $40 \times 30 = 1{,}200$ lb.; and therefore two men at such a crane could raise a ton with ease.

But we often find in cranes more than a single wheel and pinion. There are sometimes two wheels and two pinions in powerful cranes; but in all cases the mechanical efficiency may be found by the following rule:—

Multiply the diameter of the circle described by the handle into the product of the number of teeth in all the wheels.

Multiply the diameter of the barrel by the number of teeth in all the pinions.

The former of these products divided by the latter gives the mechanical efficiency of the apparatus.

Thus, for example, suppose a crane in which the handle and barrel were the same as in the last example, but that on the shaft turned by the handle was a pinion of 12 teeth, which worked into a wheel of 180 teeth, and that on the shaft carrying the latter wheel is the pinion of 20 teeth working into the wheel of 200 teeth which carries the barrel.

Now the product of the diameter of the circle described by the handle with the numbers of teeth in the two wheels is—

$$3 \times 180 \times 200;$$

and the product of the diameter of the barrel and the numbers of teeth in the pinions is—

$$1 \times 12 \times 20.$$

Hence the mechanical efficiency is—

$$3 \times 180 \times$$

$$450.$$

In a crane fitted with hoisting machinery of this kind a man exerting a power of 40 lb. could raise a load of—

$$450 \times 40 = 18{,}000 \text{ lb.}$$

The rule which we have given is very easily proved, and the reader will find it a useful exercise to deduce it from the principles laid down in Lesson VIII. in "Mechanics."

In the crane represented in Fig. 5, the mechanical efficiency is doubled by the movable pulley from which the load is suspended. Supposing this crane, then, to have the train of wheels which we have described, its mechanical efficiency would be 900.

It will be noticed that we have taken no account of the effect of friction when speaking of the crane. The reason of this is that when the machinery is in proper order the amount of friction is small. We can see at once in any crane that at all events less than half the power is lost by friction, because the weight will go down by the run if allowed to do so. In fact, this has often been the cause of very serious accidents; but we have already laid down that in no machine where more than half the power is lost by friction is it possible for the load to overrun. Hence the loss in the crane is less than a half. Practically it will not in a well-constructed crane be more than a fourth or a fifth.

THE STEAM-ENGINE.—III.

By J. M. Wigner, B.A., B.Sc.

APPARATUS—STAND-PIPE FOR LOW-PRESSURE BOILERS—"GIFFARD'S INJECTOR"—"BUCKET BOILER FEED"—SAFETY-VALVES—PRESSURE GAUGE.

The first point which demands our attention in the present paper is the manner in which fresh supplies of water are from time to time introduced into the boiler, to take the place of that which has been converted into steam. The importance of attending very carefully to this will be seen from our last paper, and from the fact, that in a large proportion of boiler explosions the cause has been found to be an insufficient supply of water.

Much attention has therefore been directed to the construction of self-acting feed arrangements, which shall act quite independently of the engineer, and thus obviate the risk of accident by neglect on his part. There is some difficulty in accomplishing this, mainly arising from the fact, that the steam inside the boiler is at a high pressure, and that the water has therefore to be forced in, and that, too, without allowing any escape of the steam.

If cold water be employed to feed the boiler, the temperature of the whole is considerably reduced, and an increased expenditure of fuel is thereby rendered necessary. This may easily be, to a great extent, avoided, for the steam, when it has accomplished its work and escapes from the cylinders, is still at a high temperature, and may therefore be advantageously used to warm the feed. In this way a considerable amount of heat which would otherwise be wasted is utilised. Arrangements are usually made by which the heated water from the condenser, or other parts, flows into a hot-well, from whence the boiler is fed.

In condensing or low-pressure engines, the waste steam is condensed by means of a jet of cold water in the condenser, and in some instances special arrangements are made, by which a portion of this water leaves the condenser at a temperature very little below the boiling-point.

The construction of the feed apparatus varies, according as the engine is a low-pressure or a high-pressure one. In the former class, the pressure of the steam in the boiler does not usually exceed that of the atmosphere by more than about six or eight pounds to the square inch, and water is then commonly supplied by means of a vertical stand-pipe with a small cistern at the upper end, as shown in Fig. 12. H is the stand-pipe, which passes nearly to the bottom of the boiler, and is of such a length, that the ordinary pressure of the steam will keep the water in it at a height a little below the level of the cistern, opening into H by means of a valve attached to the rod D.

This rod is jointed to the lever B C, and the valve is usually kept closed by the weight C. Attached to the other end of the lever is a rod, I, which passes through a stuffing-box, G, and is fastened to a float, A.

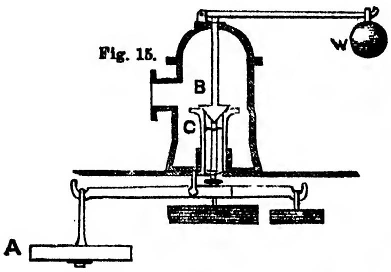


Fig. 15.

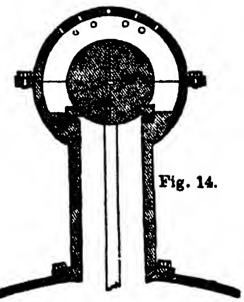


Fig. 14.

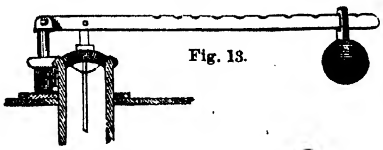


Fig. 13.

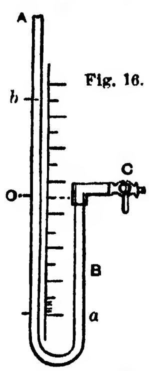


Fig. 16.

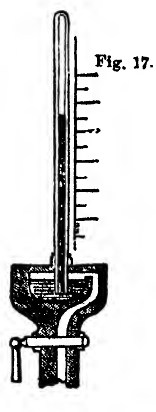


Fig. 17.

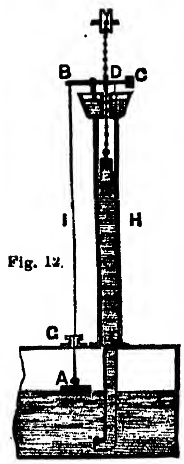


Fig. 12.

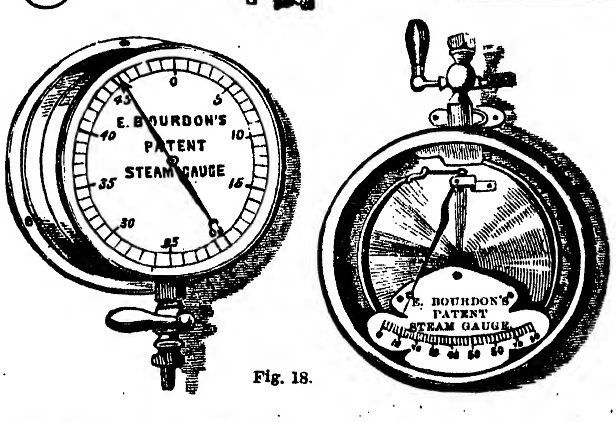


Fig. 18.

When the level of the water in the boiler falls, the float A sinks likewise, and in so doing opens the valve and allows water to pass from the cistern into the boiler till the level is restored. The weight C then closes the valve again. When the apparatus is working properly, the float keeps the valve a little way open, so that a small stream of water enters at just the rate at which it is evaporated, and thus the level does not fluctuate to any perceptible degree.

In the tube H is seen a float E, which is connected with a damper in the flues in such a way, that when the pressure of the steam increases, and the level of the water in H consequently rises, this float rises likewise, and in so doing lowers a damper which checks the draught till the pressure of the steam again diminishes. A double purpose is in this manner served by the stand-pipe: it regulates the feed, and also the draught.

There is one drawback to the use of these self-acting feed arrangements, and that is, the fear lest the valve should stick in its seat, or the rod connected with the float should become fixed in the stuffing-box, and thus cause the apparatus to cease to act. The engineer might then go on supposing that all was right, and omit to look at his gauge-glass till the boiler was seriously injured. This objection of course applies to all self-acting arrangements; but, with ordinary care, it is not a serious one. The important point is for the engineer not to trust solely to the apparatus, but frequently to consult the gauge as well, and then all danger will be avoided.

This apparatus is clearly inapplicable to high-pressure boilers, since the pressure in them is seldom less than thirty or forty pounds to the square inch, and often very much greater. A stand-pipe would therefore have to be carried to a great height, and be altogether impracticable. For these boilers, then, a different plan has to be adopted, and the most usual arrangement is to have a small force-pump to drive the water from the hot-well into the boiler. This pump can be thrown out of gear at pleasure, and a cock is usually placed in its suction-pipe, so as to limit its action when required. Sometimes this force-

pump is connected with the engine and driven by it; in other cases it is altogether separate, being worked by a small engine of its own. This latter plan is generally adopted in cases where several different engines are driven from one boiler or one set of boilers, the advantage being that the pump can be set in action even though the engines are at rest, and it is also more under control.

The engineer then observes the gauge-glass, and regulates the action of this pump accordingly. It is very desirable, however, so to regulate it that the level of the water varies as little as possible; for frequent fluctuations—even though not sufficiently extensive to endanger the boiler—render the generation of steam less uniform, and to a certain extent impair it.

A very ingenious apparatus, known as "Giffard's Injector," is now frequently employed as the means of injecting water into high-pressure boilers. The action of this is somewhat strange, since the water is forced into the boiler by the pressure of the steam on the surface of the water in the instrument, and this pressure is clearly less than that of the steam in the boiler. One great advantage of this instrument is the absence of all valves, with the exception of one placed as a check where it is connected with the boiler, and serving to prevent the escape of water when the instrument is not in action. It cannot, however, be employed when the temperature of the feed-water is much above 120°, as a part of its efficacy appears to arise from the condensation of the steam. This is a drawback to its more general adoption, since it is always very desirable to have the feed as hot as possible.

A very ingenious self-acting feed apparatus for high-pressure boilers, known as the "Patent Bucket Boiler Feed," is now extensively adopted. The construction of this is rather complicated, so that it is difficult to explain it without a model; the principle on which it acts is, however, simple. The feed-water flows into a tumbling bucket mounted on one end of a lever, the other end of which carries a counterpoise. When full, this bucket upsets into a small cistern, whence the water may flow through a valve into the feed-pipe, which passes nearly to the bottom of the cylinder, and is closed at its upper end. When the bucket is *nearly* full, it overbalances the counter-weight and turns the lever a little way; in so doing it opens a valve, which allows the steam from a special steam-pipe to enter the top of the feed-pipe, and drive the water from it into the boiler. The mouth of the steam-pipe in the boiler is just at the level at which the water ought to stand; if it rises above this, no steam can escape, and consequently no more water is driven into the boiler till the proper level is restored. As soon as the bucket is quite full, it upsets and empties itself. The counterpoise then restores the lever to its original position, and closes the steam-valve again. A waste-pipe carries off the excess of water from the cistern; and the supply should be so arranged that it may slightly exceed the consumption in the boiler.

In order to guard against the risk of explosion, should the level of the water at any time by accident or neglect fall so low as to admit of the tubes or plates being unduly heated, "fusible plugs" are sometimes employed. A short nozzle is attached to the boiler just below the lowest level at which the water may safely stand. On this there is screwed a cap, the centre portion of which is composed of an alloy that melts at a temperature not very much exceeding the boiling-point. So long as this plug is kept covered with water, it remains firm, the heat being carried away from it by the water; but should the level fall so low as to expose it, the centre at once melts, and allows the steam and part of the water to escape into the flues and furnace, damping or extinguishing the fire and at the same time removing the undue pressure. Should this happen, the boiler must be left to cool sufficiently to admit of a fresh cap being screwed on in place of the used one.

In practice it is found that these plugs cannot always be relied on, as after the lapse of a little time they become incrusted or injured by the heat, and thus lose somewhat of their efficacy. The only safe plan is to change the cap at frequent intervals. Plates of fusible metal have also been proposed to be inserted in different parts of the boiler with a similar purpose, but they have not been adopted.

The next appendage to the boiler that we must notice is a very important one—the safety-valve. Steam is frequently generated more rapidly than it is consumed in the engine, or sometimes the engine is stopped for a short time, and thus the steam is allowed to accumulate. The natural consequence is that the pressure inside the boiler goes on gradually increasing, and in a little time it would become so great as to cause it to explode with fearful violence. To guard against this risk, some contrivance is needed which shall allow the steam to escape before its pressure becomes so great as to be dangerous, but which at the same time shall, under ordinary pressure, prevent any loss. The safety-valve is intended to accomplish this object.

The ordinary form of valve is represented in Fig. 13. It is placed in some convenient portion of the surface of the boiler. The movable portion is usually fixed on a spindle, so that it may be kept horizontal, and always fall back exactly to its seat. This valve is kept closed by means of a lever, fitted either with a sliding weight or an adjusting spring, so that the pressure can at pleasure be moderated to any required extent. It is usually set so that the valve opens as soon as the pressure is a little above that at which the engine is to be worked.

One serious drawback to the use of the conical valve is its liability to become corroded and fixed into its socket, so that it ceases to act. More than one explosion has, on inquiry, been found to result from this cause. To guard against this, it is well from time to time to raise the weight, and thus allow the valve to open by the pressure of the steam. Spindles, and other arrangements for guiding the valve, are also very liable to become corroded, and thus prevent its due action. A very ingenious arrangement has been planned to obviate this difficulty, and ensure the accurate fitting of the safety-valve: this is represented in Fig. 14. The valve consists of a spherical ball with a rod passing through its centre. This ball exactly fits in a circular seat; but the chief peculiarity consists in an arrangement by which the ball is kept continually in motion, so that the surfaces in contact do not remain stationary, and therefore cannot corrode. Inside the boiler there is always a certain amount of movement in the water caused by the ebullition: a sheet of iron is therefore attached to the rod passing through the ball, and allowed to dip down some way into the water. The ebullition makes this oscillate a little, and by this means the motion of the ball in its bearings is maintained. In this way a very perfect fit between the valve and its seat is secured. The weight on this valve consists of the ball and iron attached to it, and cannot, therefore, easily be altered.

It is customary to have two safety-valves to every boiler: the one is usually either locked, or so arranged that it cannot be altered by the engineer, and this is adjusted so as to open at the highest pressure the boiler can safely bear; the other is adjusted according to the pressure of steam it is intended to employ. A boiler should always, before being used, be tested by hydraulic pressure, to ensure its being sufficiently strong. This is usually done by filling it completely with water, all openings being closed. Water is then forced in through a small aperture by means of a force-pump, which records the exact pressure in pounds per square inch. A boiler will, however, sometimes be found to leak even after having been proved in this way; since when heat is applied to it, the iron expands and some of the joints become loosened.

A form of safety-valve, now very generally employed, is known as "Hopkinson's Double Safety-valve," and is shown in Fig. 15. The special advantage of this is that it guards against explosion, either from excess of pressure or deficiency of water.

The valve is placed inside a dome, which protects it from injury; a large opening is, however, left at one side for the steam to escape. The part B has a curved surface, and accurately fits on the top of the pipe C, which communicates directly with the boiler. The weight W slides along the lever, and in this way the pressure can be adjusted to the required amount. Thus far this valve resembles that in ordinary use; the peculiarity of it consists in the internal lever and weights. The float A is so adjusted, that when the water in the boiler is at its proper level, the lever from which it hangs is horizontal, and the valve is closed. If, however, the level falls, this float sinks likewise, and in so doing raises the valve by means of the spindle under it, and thus allows the steam to escape. In some instances the steam, as it blows off from the safety-valve, is made to sound a whistle, and thus call the immediate attention of the man in charge of the engine.

There have been many other variations in the forms proposed for safety-valves, for, owing to their great importance, much attention has been directed to the discovery of the best and

safest construction; but space will not allow us here to explain the details of these.

When the lever of the safety-valve is properly graduated, the weight can be so adjusted as to allow the valve to open at any given pressure, and we at once ascertain the fact of this pressure being attained by the escape of the steam. The heat in the furnace ought, however, to be so regulated by means of dampers in the flues, that the steam shall be kept up to the required pressure, but not allowed to exceed it, since all that escapes by the safety-valve is in reality a loss of so much heat. In order to do this, we need some mode of indicating at any moment the exact pressure which the steam exerts, and this we learn by means of the "pressure-gauge."

Various forms have been given to this instrument; the simplest is that known as the mercurial gauge for low-pressure boilers (Fig. 16). It consists of a tube bent in the shape of a syphon, the longer end, A, being open, and of such a length that the pressure of the steam will not force the mercury out of it. A stopcock, C, is placed at the other end, and beyond it a screw is cut, by means of which the gauge is attached to the boiler. The bend of the tube is now filled with mercury till it stands in both limbs at the level, O; a small air-hole, closed by a screw, is often placed near C to aid in the filling. As soon, now, as the cock C is opened, the mercury in the limb B will be pressed upon by the force of the steam in the boiler, while the surface of the mercury in the other limb will be acted upon by the pressure of the air. The difference in level in the two limbs will at once show the difference in pressure. If the force of the steam be such as to depress the mercury in B to *a*, it will, of course, rise as much above O in A, and will stand at *b*. The difference in level between *a* and *b* will thus show the amount by which the pressure in the boiler exceeds that of the air, which may be taken at 15 pounds per square inch. A graduated scale is usually placed between the two limbs, by means of which the difference may easily be read off. Most commonly the tube is made of iron, as glass is very liable to be broken; a float is then placed in A, and a counterpoise is connected to it by a string passing over a pulley at the top. This counterpoise serves as an indicator, and marks the pressure on the scale.

As the difference in the level of the mercury in the two limbs amounts to about two inches for each pound of pressure, it is clear that this kind of gauge cannot well be employed with high-pressure boilers without being made very inconveniently large. A totally different form is therefore made use of, the construction of which will be easily seen by reference to Fig. 17.

A tube of strong glass, closed at the upper end, is made to dip into a closed vessel containing mercury, on the surface of which the steam presses. As this pressure increases, the air in the tube is compressed, and the mercury rises.

A specially graduated scale is placed at the side of the glass, which shows exactly the extent to which the air is compressed. If the mercury stands half-way up the tube, the air occupies just half its ordinary space; the pressure of the steam, therefore, is twice as great as that of the air—that is, it amounts to 30 pounds to the square inch. If the air is compressed to one-third of its bulk, the pressure is 45 pounds, and so on.

Mercurial pressure-gauges have, however, almost entirely given place to those known as "Bourdon's." In this there is a dial-plate, with a hand on it pointing to the pressure, as seen in Fig. 18. The steam acts upon a spring of a peculiar construction, somewhat on the plan of that used in some aneroid barometers; and, owing to their greater convenience, these gauges are now almost universally adopted.

COLOUR.—IV.

By Professor A. H. Church, M.A., Royal Academy.

MAXWELL'S THEORY OF PRIMARY COLOURS.

In continuation of our remarks upon the various theories which have been propounded as to the true primary colours, we may now refer to the conclusions of Professor Clerk Maxwell. According to this observer, the three primary colours are scarlet, green, and blue. By the combination of these colours he considers that all others may be formed; but at the same time he admits that the other colours of the spectrum are due to simple or undecomposible rays, though they excite the same sensations as of certain mixtures of rays. A bluish-green ray, for example, though not compounded of blue and green rays, produces a sensation which may be regarded as compounded of those sensations which are produced by blue and green. In their selection of the three most important colours of the spectrum, in their divergence from the ordinary theory as to the primary colours, and in their views as to complementary colours, Helmholtz and Maxwell agree to a considerable extent: it is as to the possibility of forming from three colours all the others that they differ—Maxwell affirming this, and Helmholtz denying it. A few words as to the primary, secondary, and complementary colours admitted by Maxwell may now be given. In order to observe these colours satisfactorily, the following contrivance should be adopted:—Two slips of pure white unglazed paper should be laid upon a piece of black velvet, after the manner represented in Fig. 9. If this diagram be thus copied in paper and velvet on a large scale, and viewed from a distance, by means of a prism having its refracting edge turned away from the spectator, the colours will be seen as indicated in the figure. These colours are the two complementaries. By varying the shape of the black and white spaces, new and instructive effects may be developed, which we have not space to describe particularly. One of these variations is made by placing a narrow white strip across the middle of a long black band, and a similar narrow black strip across a contiguous long white band, and continuous with the white strip.

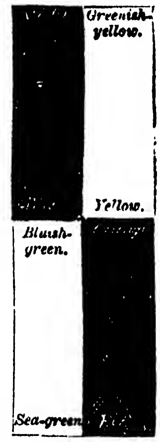


Fig. 9.

According to the deductions of Maxwell, the most effective three primary colours for the purpose of compounding the largest numbers of other colours have the following wave-lengths in millionths of an inch, and the following positions in the spectrum of the sun (Fig. 10):—

Names of Primaries.	*Wave-lengths.*	*Positions.*
Pure red or scarlet	2,328	⅙ from line C to D.
Pure green	1,914	¾ from line E to F.
Pure blue	1,717	½ from line F to G.

The secondary colours complementary to these primaries are—

Sea-green,	*complementary to*	Red.
Almond-blossom	,,	Green.
Yellow	,,	Blue.

Some authors call the colour we have here named "almond-blossom" pink, others peach-blossom. It contains less blue than does violet, which is not its true complementary. The best representation of the particular colour here meant is to be obtained by burning the gas known to chemists as cyanogen—easily obtained by heating a little mercuric cyanide in a short test-tube fitted with a fine glass jet to serve as a burner.

These three secondary colours, in order to be truly complementary to their several primaries, must not only be of the right quality and purity, but must be of the right intensity or brightness. So the sea-green named above must have the added brightness of its two components, blue and green; the almond-blossom must have the added brightness of its two components, red and blue; and the yellow must have the added brightness of its components, red and green. Of course these statements refer only to Maxwell's theory of the colours of light. In the case of pigments we shall have frequent occasion further on to repeat what we have indeed often stated before—that the complex nature of the coloured rays they generally reflect does not permit these simple relations of colours to each other to hold good. In concluding our brief outline of some of the chief features of the new theory of colour, we may draw our readers' attention to the following diagrams (Figs. 11 and 12) by means of which, when filled in with the colours named, they can represent for themselves the primary and secondary colours of Maxwell's theory.

In these diagrams the following abbreviations are used:—

I. *Primary Colour.*—R, Red; G, Green; B, Blue.
II. *Secondary Colour.*—S G, Sea-green; A, Almond-blossom; Y, Yellow.

When the diagrams are filled in with the purest pigments attainable, then Fig. 11 should show the effect of taking away the three primary colours from white, leaving three overlapping circles of secondary colours where only one colour is removed;

leaving three-sided spaces of primary colours where two colours are removed; and leaving also a similar space of black or darkness in the centre, where all three primaries are equally removed. The exact converse of this effect is shown in Fig. 12, where the primary colours are supposed to be represented in equal strength upon a black ground. They form, by the overlapping of two of the three circles or discs containing them, three spaces of the secondary colours, and where all three circles overlap or coincide, a central space of white. Coloured lights are, of course, alone competent to produce secondary colours brighter or more luminous than their constituent primaries. A similar but thoroughly false imitation of this effect is produced by mixing white with the secondary colours used in preparing the above diagrams.

The more commonly received theory of the primary colours must now be described. It is still adopted in all the manuals of design and colour as applied to the decorative and fine arts; indeed, the authors of such books seem to be ignorant of the existence of the more correct views which have just been described. One great advantage is possessed, we readily admit, by the old theory—it works far better with actual pigments than does the new one. It breaks down more or less completely when tested, by the means we have already mentioned, with coloured rays of light. Concerned as we usually are with coloured materials and not with coloured rays, we shall describe the old theory at some length, particularly as it affords an easy means of studying the mixed colours which pigments afford.

In our coloured diagram* we have arranged the most important colours in a six-pointed star made of twelve equilateral triangles. The whole figure being regarded as consisting of two intersecting triangles, the three primary colours will be found in the angles of one of these, the three secondary colours in the angles of the other, and the more mixed hues in the area where the two triangles coincide or overlap. However, before showing how the compound colours may be supposed to originate from the admixture of simple ones, it will be necessary to define the meanings of a few words which we shall have frequent occasion to employ.

Tones, often called shades, signify colours mixed with varying proportions of white or black. In mixing a colour with white we weaken or reduce its tone, but by the addition of black a colour has its tone broken or darkened, not deepened. Red mixed with white in increasing proportions gives weaker and weaker tones of red; red mixed with black in increasing proportions gives duller and duller tones of red; while red mixed in a similar manner with both white and black—that is, grey—gives a series of tones of red which are at the same time duller and weaker than the original colour.

A *scale* is a regular series of such tones as those just described. Every colour admits of three scales:—

1. The reduced scale—that is, the normal colour mixed with white, thus forming *tints*.

2. The darkened scale—that is, the normal colour mixed with black, thus forming *shades*.

3. The dulled scale—that is, the normal colour mixed with both white and black, or, in one word, with grey.

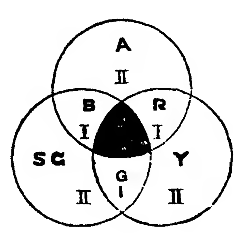


Fig. 11.

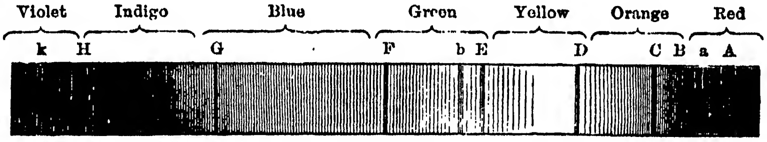


Fig. 10.

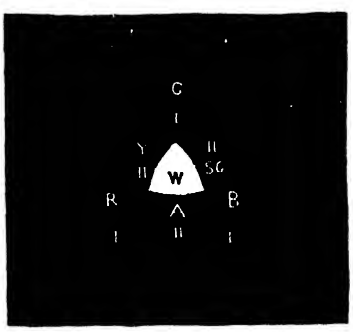


Fig. 12.

Primary or elementary colours are usually regarded as three in number, and are assumed to be capable of yielding by combination all other colours. They are commonly assumed to be yellow, red, and blue.

Secondary colours are mixtures of two primaries in equivalent proportions. Orange, green, and violet are the three secondary colours. We say equivalent, not equal proportions; for it will be found that equal quantities of yellow and red lights, or of the purest yellow and red pigments attainable, will not produce the normal orange. In making, therefore, such a secondary colour as orange, we have to judge by the eye what quantities of its primary constituents will produce a colour equally removed from yellow on the one hand, and from red on the other.

Tertiary colours are mixtures of the three primary colours in certain proportions, which will be noticed presently. All tertiary colours are dull, owing to the following fact. All pigments representing the three primary colours produce, when mixed together in equivalents, not whiteness, but greyness or blackness. In tertiary colours, therefore, the equivalents of yellow, red, and blue which are present, unite to neutralise one another, and so to form grey; while it is only the unneutralised residue of the one or two colours that are in excess which gives a special character to the final result. The neutral grey of the tertiaries, as thus produced, dulls all their tones, and distinguishes them at once from the primary colours, and from all combinations of two primaries. Indeed, the six normal tertiary colours are nothing more than the *dulled* tones of the three primary and the three secondary colours.

Hues include all tertiary colours, and all those colours in which the primaries are mixed in other proportions than are requisite to form the secondary colours. Yellowish-orange and bluish-green are secondary hues; reddish-grey and violet-grey are tertiary hues.

With these definitions of terms before us, the consideration of the chief colours, of the quality and optical composition of coloured materials, and of the pigments in actual use, may be commenced.

The Primary Colours.—*Yellow.*—The most luminous of all colours is the pure yellow. It occupies a very narrow space in the solar spectrum, but is distinctly the brightest part of it. Most yellow pigments and coloured materials reflect or transmit much orange and red light, as well as yellow. Chrome yellow is an example of this fact. Some transparent yellows on a white surface, such as gamboge, allow the transmission of, or reflect much white light, in addition to the yellow rays which characterise them. They are in reality reduced yellows—yellow, that is, mixed with white. Yellows occasionally verge upon green, especially in their lighter tints. This effect is partly due to their reflection of some green rays in place of the red which they usually emit, and partly to the result upon the eye of contrasting the lighter or reduced tones of yellow with the darker tones which verge upon orange and red. An orange or even a red tint is often perceived in yellow pigments when they become dry, though they may have appeared of a nearly pure yellow when wet. Fibres of wool, silk, cotton, etc., dyed yellow, exhibit the same appearances, as to the optical constituents of the colours they reflect, as do other white surfaces of paper, canvas, and porcelain, upon which opaque or transparent pigments have been spread. In all cases varying proportions of white light are reflected; while of the light which is decom-

* The coloured diagram will be found in another part of The Technical Educator.

posed by the coloured surfaces, different but considerable amounts of violet, indigo, blue, and, in a measure, green, are quenched or absorbed. The remaining rays produce the colour effect of the object, and will, of course, consist mainly, but not entirely, of yellow light. With stained glass and other transparent materials, such as coloured gelatine and coloured liquids, similar groups of violet and blue rays are on the one hand absorbed, while on the other hand the less refrangible colours are transmitted.

Red.—The second primary colour in point of vividness is red. It is less luminous than yellow, but warmer and more retiring. All our ordinary red colours contain orange and yellow, or else blue and violet. A stick of sealing-wax examined by a prism is found to reflect all the rays up to the line D in the yellow—that is, the colour which it presents is made up of much orange and a little yellow in addition to the true red. The fugitive paint known as geranium colour is a purer red than that just named, the vermilion of sealing-wax, but it is not free from a tint of orange. Carmine and crimson lake, with other similar pigments, reflect to the eye a trace of the blue and violet, as well as nearly all the red, and some of the orange rays of the light which falls upon them. The best idea of pure redness may be got from the bright and broad red band in the spectrum of a burning lithium salt. Red glass, at least that kind of red glass which is coloured by copper suboxide, does not transmit unmixed red rays, but many orange rays as well.

Blue.—The third and least vivid of the primary colours is blue. It is also the most retiring and cool. We cannot point to any tolerably pure blue pigment. Beautiful as ultramarine undoubtedly is, its spectrum reveals the existence of several colours besides blue. Yet it would be hardly fair on this account to regard this or any other colour as impure. If the various coloured rays which a pigment reflects to the eye impart the sensation of blueness, it is enough. They may contain red, violet, and other constituents, but the resultant effect of the combination may be a blue indistinguishable in purity from the normal blue of the solar spectrum. A difficulty does, however, arise when such pigments as those above referred to are illuminated by artificial light, or are mixed with others to form secondary and tertiary colours; the anticipated result being occasionally very far from being realised. Cobalt-blue reflects much green and violet light, as well as blue, and in fact shows a very remarkable combination of colours when its spectrum is examined. On mixing it with carmine, to form a violet hue, the green constituent in its light interferes with the purity of the resulting colour, which is much greyer than one would have expected. By lamp-light cobalt-blue appears violet. Prussian-blue and indigo absorb most of the red, orange, and yellow rays, but emit a very large part of the green, blue, and indigo. A crystal of blue vitriol (copper sulphate) cuts off all the red, orange, and yellow rays, together with the green rays up to line E, and transmits the remainder.

The secondary and tertiary colours remain for discussion in our next lesson.

SEATS OF INDUSTRY.—III.

MANCHESTER AND ITS SUBURBS: THEIR CHIEF INDUSTRY.

BY H. R. FOX BOURNE.

MANCHESTER has an antiquarian history, extending over nearly twenty centuries, and a commercial history, the authentic records of which hardly cover five hundred years. It ranks however, with the oldest English towns that attained importance by their manufacture of clothing and other textile goods.

Its first staple manufacture was not cotton but wool. When, in 1331, a few of those industrious Flemish emigrants who instructed the English in better ways of turning sheep's wool into cloth settled in Manchester, they gave new life to a trade that for some time previously had been feebly carried on. Two centuries later, one of the three most famous clothiers in England was Martin Brian, or Byrom, of Manchester; and at that time, in 1538, the town was spoken of by Leland as "the fairest, best builded, quickest, and most populous town of all Lancashire."

Linen manufacture, as well as woollen manufacture, had a share in making what is now the greatest of all the great cotton towns. "The town of Manchester," it was written in 1542, "is and hath of long time been inhabited, and the inhabitants of the said town have come into riches and wealthy livings, and have kept and set many artificers and poor folks to work within it; and by reason of the great occupying, good order, straight and true dealing of the inhabitants, many strangers, as well of Ireland as of other places, have resorted to the said town with linen yarn, wool, and necessary wares for making of cloths, and have used to credit and trust the poor inhabitants, which had not ready money to pay in hand, unto such time as the said debtors with their industry, labour, and pains, might make cloths of the wools, yarns, and other necessary wares, and sell the same, to content and pay their creditors; wherein hath consisted much of the common wealth of the town." That account of the help given to poor Manchester weavers by rich Irish merchants furnishes a curious illustration of the relative position of Irish and English which has so strangely altered during the last three centuries.

It is not necessary to note in detail the stages of the progress of Manchester during those three centuries. It grew steadily by help of wool and linen, although the progress was slow indeed in comparison with that of the past century, in which cotton has been the staple. In 1757, Manchester and Salford, then quite a distinct town, had between them hardly 20,000 inhabitants. In 1861 their population was 460,000, and in 1881 it was 480,470. The real Manchester, however, is very much more than the Manchester on the Irwell with its half a million inhabitants. Thirty or more important towns in southern Lancashire and western Yorkshire, and in the adjoining counties of Derbyshire and Cheshire, each with its own group of suburbs and outlying villages, constitute a vast network of cotton factories, with Manchester for the head and centre of the whole.

The development of the Lancashire cotton trade furnishes one of the most remarkable episodes in commercial history. It had a slender existence more than two centuries ago. "They buy cotton wool in London that comes first from Cyprus and Smyrna," it was said in 1641 of the Manchester manufacturers, "and at home work the same and perfect it into fustians, dimities, and other such stuffs, and then return it to London, where the same is vended and sold, and not seldom sent into foreign parts." While all the cotton wool that reached England came from the Levant, the supply was so small that no prejudice was excited by its use. As soon, however, as the East India Company began to bring home larger quantities, which were worked up both in the Manchester districts and elsewhere in England, the dealers in woollen goods began to fear that their own trade would be interfered with, and accordingly, using all their influence in Parliament, they obtained the passing of a series of laws, by which such heavy taxes were laid on cotton manufactures that for a time they were virtually prohibited. In London, and along the Thames, where Huguenot settlers had planted the trade, it was nearly stamped out. In Manchester it was carried on with difficulty until 1774, when the foolish laws were rescinded. The trade, thus relieved, had a little while before begun to be quickened by the arrival of cotton wool from the West Indies, and the American colonies which have now become part of the United States. The trade in England encouraged these new importations. The invention of new machines for spinning and weaving further encouraged them; and these causes, influencing and being influenced by the favour shown by the people for the new and cheap material for clothing, caused a marvellous extension of the trade. In 1768 the cotton goods manufactured in the whole of Great Britain were worth less than £200,000. By 1788 the trade had been more than doubled, and it was then large enough to give employment in spinning and weaving to 159,000 men, 90,000 women, and 101,000 children. Of 142 water-mills used in these manufactures, 41 were in Lancashire, 22 in Derbyshire, and 8 in Cheshire; that is, just half were in the district of which Manchester was the centre. In 1835 the number of factories in the Manchester district amounted to over a thousand, and the hands employed in them, and in connection with them, cannot have been far short of a million. In 1860, said Mr. Bazley, "the number of spindles employed was about 32,000,000, and the number of looms employed would be about 340,000. The paid investments, including the value of land and the right of water, amounted to not less than £60,000,000, to which must be added a working capital of £20,000,000. Add to these again the value of merchants' and tradesmen's stocks at home and abroad, the value of raw cotton and subsidiary materials, and of bankers' capital, and the grand total of capital employed in the trade will not be

less than £200,000,000." No other single trade is so vast in its dimensions or so important in its influences on society as the cotton manufacture, which has Manchester for its centre. In recent years Manchester has become noted for its warehouses rather than its factories, the increasing value of sites within the town having driven the factories and mills out into the surrounding villages.

All the circumstances of the trade have grown in proportion. Dr. Aiken, the old historian of the town, tells how, a century and a half ago, "an eminent manufacturer used to be in his warehouse before six in the morning, accompanied by his children and apprentices. At noon they all came into breakfast, which consisted of one large dish of water pottage, made of oatmeal, water, and a little salt, boiled thick, and poured into a dish; at the side was a pan or basin of milk, and the master and apprentices, each with a wooden spoon in his hand, without loss of time, dipped into the same dish, and thence into the milk-pan; and as soon as it was finished they all returned to their work." Those simple ways gradually gave place to more refinement and conventionality; but the accounts of old Robert Peel's early life, and of his commencement of calico printing, show a state of things almost as primitive. As Peel grew rich, and became the master of a score of mighty factories, giving work to 1,500 hands, so Manchester and its suburbs have grown. The old modes of labour, by which each cottage was generally a distinct workshop, and each workman his own master, have been displaced by arrangements which necessitate the presence of hundreds of workpeople under one roof to manage the complicated machinery now in vogue, and that machinery enables each hand to get through fifty or a hundred times as much work as the old tools rendered possible.

The numerous stages of cotton manufacture may be grouped under three divisions. The first comprises all the processes by which the great lumps of cotton wool brought from the United States and other parts, through Liverpool, to Manchester and its suburbs, are reduced to yarn fit for weaving. The cotton is, in the first instance, *cleaned* by removing all impurities, and separating the coarser from the finer qualities. Then it is *carded*, that is, all tufts and knots are removed, and the fabric is laid out in a fleecy ribbon-like web. Next it is *drawn*, so that the ribbons may be all of the same quality and texture, and the filaments all exactly parallel. After that it is *roved*, a process by which each ribbon is greatly attenuated, and at the same time slightly twisted, so as to give it more strength and consistency. *Fine roving* follows, being, as the term implies, a more delicate repetition of the former operation. The sixth process is the *spinning*, which completes the production of the yarn, except that it has to be wound and packed before it is ready to be passed over to the weaving-shops. All these processes hang together, and are generally carried on in one department. The weaving is often conducted in the same factory, but it need not be so, and many cotton colonies are for spinning and nothing more. The weaving stage consists of fewer processes, but these are more complicated, some of the most wonderful exploits of modern invention being concerned in the adaptation to vast machinery of the same principles which guided the hands of the old weavers and websters during the thousands of years that preceded the introduction of machinery. We hope to be able to describe these in a future number, as well as the interesting processes of the third stage, in which the cotton wool, now converted into cloth, is dyed, printed, or otherwise finished, so that it may go out for sale as muslin or calico, wearing apparel, curtains, counterpanes, or anything else. Bleach-works, dye-works, print-works, and the like, all come under this category, and complete the circle of cotton manufacture.

The substitution of these comprehensive mechanical arrangements for the old-fashioned modes of handiwork has effected a mighty revolution in the social condition of the people. The history of that revolution is full of interest. Looking back at the Manchester people of bygone times, we see a notably industrious and independent race. Looking at them now, we see that both industry and independence have increased, in spite of changes fraught with danger and discomfort. A century ago the Lancashire spinners and weavers thought themselves superior to all the world—as, indeed, they were—in their craft. The craft gave them unusual freedom, and sufficient profit to ensure for them more luxuries than any other craftsman could enjoy. They looked with extreme jealousy upon the improved machinery that was introduced by Hargreaves, Arkwright, Crompton, and others, seeing clearly that thereby their cottage-workshops would soon be rendered impossible, and a new order of things would be introduced. Hence the Blackburn riots and other disturbances throughout Lancashire, which forced old Robert Peel and the other best friends of the cotton industries to use rough means for adopting the improvements and extending their trade. They succeeded, and the trade has been indeed extended. The cotton lords have, perhaps, in many cases, gained an unfair share of the benefit that has ensued, but the cotton operatives have also gained very much. They have found out the way to preserve their old independence, while they have come to be, in one sense, merely well-wrought tools in a vast conglomeration of machinery. You cannot walk through the streets of Manchester, or any other cotton town, without being struck by the self-sufficient bearing, the rough, honest look, and the almost painful intentness of purpose shown in every movement and aspect of every man, woman, and child. There is room for much further education, and especially hygienic education, among the cotton operatives; but England may be proud of them as they are, and the pride passes into reverence when we recall the history of their patient heroism, self-sacrifice, and mutual trust during the terrible period of the cotton famine, consequent on the American civil war.

Some mention of the multitudinous trades carried on in Manchester and its suburbs in dependence on the cotton manufacture, or apart from it, must be reserved for another paper.

VEGETABLE COMMERCIAL PRODUCTS.

VII.

PLANTS USED IN THE PREPARATION OF NUTRITIOUS AND STIMULATING BEVERAGES (*continued*).

GRAPE (*Vitis vinifera*, L.; natural order, *Vitaceæ*).—The wines of commerce are mostly prepared by fermentation from the juice of the grape. The vine ranks next to the tea and coffee plants in importance. The excellence of its fruit, whether fresh, or dried in the form of raisins, is well known. The virtues of its fermented juice have been eulogised in song by poets, and its excessive abuse has furnished a theme for moralists of every age and nation.

The grape varies in the colour, form, size, and flavour of its fruit. These varieties have all probably been produced by long-continued cultivation in different soils. This lengthened attention which the vine has received has given it an extensive geographical range. The vine may be found in all countries on the earth's surface included between the parallels of latitude 51° N. and 33° S. But the same latitude does not always permit the grape to ripen enough to make good wine; this depends on the average clearness or cloudiness of the atmosphere throughout the year.

The vine is generally supported by props and trellises, but in the sandy districts of Spain it is allowed to trail upon the ground. The time of the grape harvest, or vintage, is always regulated by the character of the wine to be made. For a brisk wine, such as champagne, the grapes are gathered before fully ripe; for a dry, full-flavoured wine, such as port, the mature grapes are selected; and for German wines, the driest of all wines, the vintage is made as late as possible. The process of wine-making is as follows:—

The grapes are gathered into baskets, which are emptied into a tub, with holes at the bottom, called the wine-press. This tub is placed over another much larger, named the wine-vat. A man then gets into the upper tub, and presses or crushes the grapes by treading upon them—a mode of bruising the grape as ancient as wine-making itself. The juice or *must*, as it is termed, flows from the press into the vat, and sometimes within a few days, or even a few hours, depending on the temperature, begins to ferment. This fermentation makes the liquor turbid, increases its temperature and volume, so that it quickly commences to fill the vat. After a time the fermentation ceases, the liquor diminishes in temperature and bulk, and becomes cool and clear. When quite cold it is drawn off, or racked, as it is termed, from the vat by a tap placed a few inches above the

bottom, into an open vessel, whence it is conveyed into the casks prepared for its reception. After entering the cask, a second, although much slighter, fermentation takes place, which further clarifies the wine; its subsidence diminishes the bulk of the wine in the cask, and more wine is added so as nearly to fill the cask. This again slightly renews the fermentation, and the cask is kept open until filled to its utmost capacity with wine free from fermentation; it is then closed, and is ready for the market.

It requires great attention and practical skill to manage the fermenting process properly, as on this depends the quality of the wine. Wines vary according to the amount of sugar, alcohol, and acid which they contain. When wines contain much sugar, they are called "sweet;" when little, "dry." Sweet wines, such as Malaga and Tokay, are wines which have been only half fermented; their sweetness depends on the fermentation not having exhausted the sugar. Dry, strong wines, such as Madeira, sherry, Marsala, and port, are fully fermented wines, all the sugar of the grape having been converted into alcohol. Champagne and other sparkling wines owe their briskness to the presence of carbonic acid; whilst hock and the Rhenish wines generally, and many of the French, contain much uncombined acid. The roughness and flavour of the red wines are usually derived from the husks of the fruit, but are often communicated to them by the addition of astringents, such as rhatany, kino, etc. The tints of wines are either natural or artificial. Their strength is frequently augmented by the addition of brandy. This brandy is itself distilled from wine. It is coloured with burnt sugar, and peach kernels are added during the distillation to give it that peculiar flavour by which it is distinguished.

The principal wine countries in Europe are France, Spain, Portugal, Germany, Sicily, Italy, Hungary, Greece, and Turkey.

France holds the first rank. The principal French wines are white and red champagne, white and red Burgundy, white and red Medocs from Bordeaux, Rhone wines, and wines from Languedoc, Roussillon, Orleans, Alsace, and Corsica. The inferior white wine of Bayonne, and Bordeaux wine, pass under the name of French wine, *vin ordinaire*.

From Germany we receive the celebrated Rhine wines, so called from their place of culture—the valley of the Rhine and its tributary streams; wines from the Palatinate, principally from Rhenish Bavaria; wines from the Bavarian province of Lower Franconia; Moselle wines from Rhenish Prussia; and Tauber wines from Baden and Wurtemburg. The chief places for these wines are Mayence, Coblenz, Frankfort-on-the-Maine, and Würzburg.

The vine is cultivated to some considerable extent on the Danube in Lower Austria, also in Tyrol and Illyria; but the exportation is small. Moravia, Silesia, Bohemia, and Saxony grow inferior wines. Artificial champagne is made in many parts of Germany, especially at Esslingen, Stuttgart, and Mayence.

The best *Swiss wines* are the Ryff wines, from the Canton de Vaud, the *Vin de la côte* from the shores of Lake Geneva. Of *Hungarian wines*, Tokay is the chief, and is largely exported to Moravia, Silesia, Poland, and Prussia. Of *Spanish wines*, Malaga and Alicante are the most valued, and called after the names of the places which export them. From Oporto in Portugal we receive red and white port wine. Numerous varieties of Italian wines come into commerce. Europe also obtains Madeira wine from the island of Madeira, on the northwest coast of Africa; Cape (Constantia) wine from the Cape of Good Hope, and palm wine from the East Indies. Young and inferior wines, and the lees of wine, or the sediment at the bottom of the wine-vat, are used in the manufacture of cognac, or French brandy, and vinegar; these come into the market from Bordeaux. *Australian Wines* have obtained considerable repute, in consequence partly of the Indian and Colonial Exhibition which was held in London in 1886.

Hops (*Humulus lupulus*, L.).—The hop vine, so well known in England, is a native of Europe, and probably also indigenous in North America, as it has been found growing apparently wild on the banks of the Mississippi and Missouri. It is extensively cultivated for its strobiles or cones, so largely employed in the preparation of malt liquors. These strobiles, or female catkins, when fully ripe, are picked from the vines, dried in kilns, and packed in bags. Hops consist of thin, translucent, veined, leaf-like bracts or scales, of a greenish-yellow colour, having near their base two small, round, dark seeds. Hops are somewhat narcotic and their odour fragrant, the taste bitter, aromatic, and slightly astringent. These properties are owing to the presence of a peculiar resinous secretion in the glands, which has been called "lupulino." Ale and porter owe their bitter flavour and tonic properties to the hops added to them during the process of brewing—about one pound of hops being added for every bushel of malt. About 550,000,000 gallons of ale and porter are annually brewed in this country. The importation of hops in 1886, chiefly from the Hanse Towns, Holland, Belgium, and the United States, was 152,759 cwts., valued at £447,253.

VI. PLANTS PRODUCING WHOLESOME AND NUTRITIOUS FRUITS.

The fruits of commerce are very numerous and interesting. They come to us from almost every climate and country; an immense amount of shipping is engaged in bringing them across the seas, and employment is thus given to hundreds of thousands of people. Besides furnishing us with nutritious food, these fruits give us much novel and interesting information in regard to the economy of vegetation in foreign countries. They are arranged naturally into two divisions, viz., fleshy fruits and nuts.

(*a*.) FLESHY FRUITS.

Of these one of the most important is the

Sweet Orange (*Citrus aurantium*, Risso; natural order, *Aurantiaceæ*).—This is one of our commonest foreign fruits. The orange-tree is a medium-sized evergreen, with alternate, bright-green, elliptical, pellucid-glandular leaves, furnished with winged footstalks; the flowers are white, and very fragrant. Both the ripe and unripe fruits are frequently seen on the tree at the same time along with the flowers—their presence amongst the foliage being truly ornamental, and adding greatly to its beauty. China is generally considered to be the native country of the orange-tree, where it still grows wild. It is said to have been brought to Portugal in 1520, and thence it has been transplanted into every country possessing climate suitable for its culture. It is now grown in China, Portugal, India, Northern and Southern Africa, Southern Europe, Turkey, the islands of the Mediterranean, the Azores, the West Indies, and the Southern portion of the United States.

The oranges imported into Great Britain come chiefly from the Azores, Lisbon, Malta, Italy, Sicily, and Spain, in boxes and chests, and grow in those countries in the greatest profusion. It is said that a single orange-tree in St. Michael's has produced a crop of 20,000, exclusive of those unfit for use, calculated at 10,000 more. In 1886, 4,388,291 bushels of oranges and lemons were imported into the United Kingdom, valued at £1,488,341.

The rind of the orange yields by distillation a fragrant oil much used in perfumery; a still more agreeable oil, with which eau-de-Cologne is perfumed, is distilled from orange flowers. The rind is also boiled in sugar until it is candied, and thus converted into a sweetmeat. The orange contains much saccharine matter and mucilage, forming an agreeable acid, and hence is wholesome, cooling, and refreshing to the sick, especially in cases of fever and inflammation.

The Bitter or Seville Orange (*Citrus vulgaris*, L.).—This species closely resembles the sweet orange, but is easily distinguished from it by the form and bitterness of its fruit. These oranges are chiefly used in making marmalade. The rind has a place in the British Pharmacopœia from its qualities as a tonic.

Citron (*Citrus medica*, L.).—This kind closely approaches the lemon-tree in appearance, with which it has sometimes been confounded. The chief differences are its naked petiole, its greater number of stamens, and the superior thickness of the rind of its fruit. The fruit of the citron sometimes attains a very great size, weighing upwards of twenty pounds. The citron itself is not eaten, but the thick rind is much used as a preserve, and reaches England either already candied or else pickled in salt and water for the purpose of being candied on its arrival. We receive annually from Madeira about seventy tons of this preserved rind. An essential oil (*Oleum citronella*) is obtained from the rind of the citron, very fragrant, and much used in perfumery.

TECHNICAL DRAWING.—XIV.

DRAWING FOR JOINERS (*continued*).

Figs. 145 and 146, combined into one view, are two designs for wooden gates, and are so simple that they will scarcely require any instructions as to copying.

The posts *m* and *n* are, of course, to be drawn first; then the base, *k*, and moulding, *l*; next the framing, *a*, *b*, *c*, *d*, of each gate.

In Fig. 145 the rail, *e*, is to be drawn next; and in the upper compartments the quatrefoils, *g*, and in the lower, the bars, *i*, and curved stay are to be drawn.

In the rectangle formed by the framing in Fig. 146 draw diagonals, and at their intersection the circular opening. Now draw the cross-framing, *o p*, and the vertical bars. The details will then be added without much difficulty.

GOTHIC TRACERY.

Although, as has already been stated, the whole subject of Gothic architecture, in both stone and wood, will be treated of in special lessons, still a few examples of tracery are given here, knowing that the joiner is often called upon to put such together on panels in churches or mansions, and that a knowledge of the basis of the construction will be of service to him. The limits of the present course of lessons, however, utterly preclude a systematic treatise on the characteristics of the several periods of mediæval art. These examples will, however, in some degree prepare the pupil for the subsequent and more extended study.

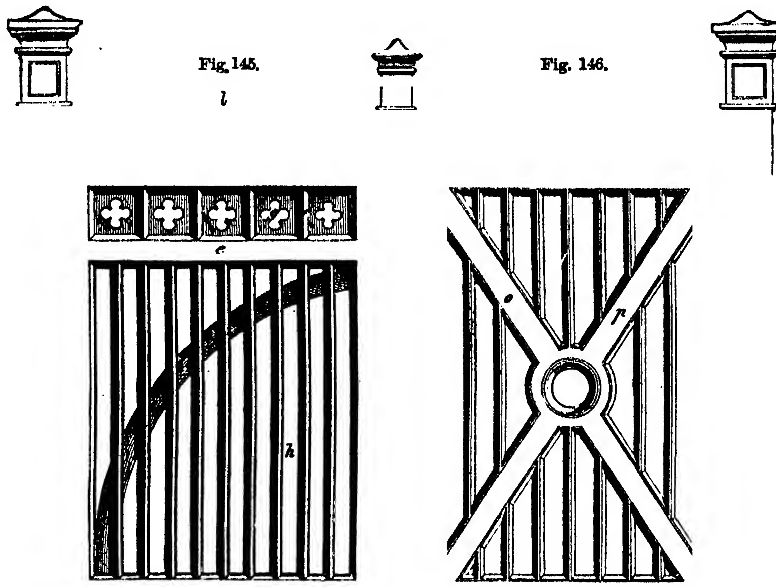


Fig. 145. Fig. 146.

Fig. 147 is the elementary figure upon which the subsequent design is based.

Having drawn the circle, describe on the diameter two opposite semicircles, meeting at the centre, *a*.

Divide one of these into six equal parts, and set off one of these sixths from *i* to *n*.

Draw *a n*, and divide it into four equal parts. From the middle point of *a n* draw a line passing through the centre of the semicircle, and cutting it in *c*. From *c* set off on this line the length of one of the fourths of *a n*.

This point and the two in *a n* will be the centres for the interior curves.

Fig. 148 is the further working out of this elementary figure. It is desirable that a larger circle should be drawn. Then, when the figure has been carried up to the stage shown in the last, all the rest of the curves will be drawn from the same centres.

Fig. 149 is the elementary form of the tracery shown in Fig. 151, and is based on the problem, "To inscribe three equal circles in a circle" (in "Practical Geometry applied to Linear Drawing"), which, in order to save the student the trouble of reference, in the event of his not being quite certain as to the construction, is here repeated in connection with Fig. 152.

At any point, as A, draw a tangent, and A G at right angles to it.

From A, with radius O A, cut the circle in B and C.

From B and C draw lines through O, cutting the circle in E and D, and the tangent in the point F (and in another not given here, not being required).

Bisect the angle E F A at F, and produce the bisecting line until it cuts A G in H. From O, with radius O H, cut the lines D C and E B in I and J. From H, I, and J, with radius H A, draw the three required circles, each of which should touch the other two and the outer circle.

Returning now to Fig. 149, having inscribed three equal circles in a circle, join their centres, thus forming an equilateral triangle. From the centre of the surrounding circle draw radii passing through the angles of the triangle and cutting the circle in points, as *d* and two others. Draw *e d*, and bisect it by *c g*; then the centres for the curves which are in the semicircle will be on the three lines *d c*, *c g*, and *c e*.

These curves are called *foliations*, or *featherings*, and the points at which they meet are called *cusps*.

The completion of this study is given in Fig. 151.

Fig. 150 shows the elementary construction of Fig. 153.

Draw two diameters at right angles to each other, and join their extremities, thus inscribing a square in the circle.

Bisect the quadrants by two diameters cutting the [illegible] the in points, as *g*. Join these points, and a second square will be inscribed within the first.

The middle points of the sides of this inner square, as *b*, *c*, *d*, are the centres of the arcs which start from the extremities of the diameters.

From *b*, with radius *b d*, describe an arc, and from *g*, with radius *g c*, describe another cutting the former one in *e*. Then *e* is the centre for the arc *i g*, which will meet the arc struck from *b* in *i*. Of course, this process is to be carried on in each of the four lobes.

Fig. 153 is the completed figure. The method of drawing the foliation will have been suggested by Fig. 148, and is further shown in the present illustration.

Fig. 154 shows the skeleton lines of Fig. 155. Divide the diameter into four equal parts, and on the middle two, as a common base, construct the two equilateral triangles *o i n* and *o i m*.

Draw lines through the middle points of the sides of the triangles, which, intersecting, will complete a six-pointed star in the circle, the angles of which will be the centres for the main lines of the tracery.

Fig. 155 is the completed figure.

The small figures, 156 and 157, will be understood without further instruction than is afforded by the examples.

Fig. 158 shows the construction of the tracery in a square panel.

From each of the angles of the square (the inner one in this figure), with a radius equal to the length of the side of the square, describe arcs; these intersecting will give a four-sided curvilinear figure in the centre. Draw diagonals in the square.

From the point *b* where the diagonal intersects the curve (the middle line of the three shown in the figure) set off on the diagonal the length *b m* equal to *b c*.

From *q*, with radius *m q*, describe an arc *o m r*, cutting the original arc *w* in *o*.

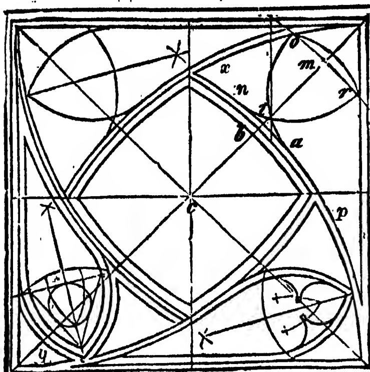


Fig. 158

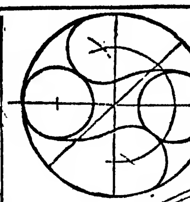


Fig. 164.

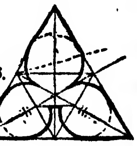


Fig. 156.

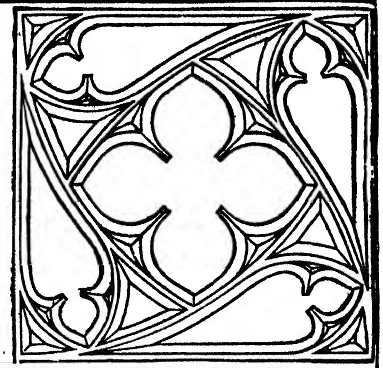


Fig. 159.

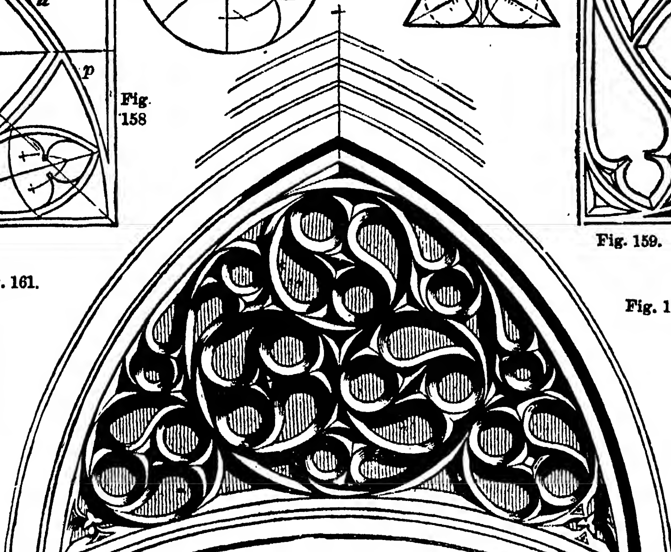


Fig. 162.

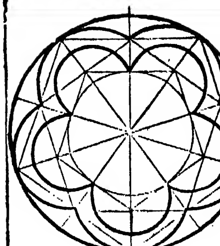


Fig. 161.

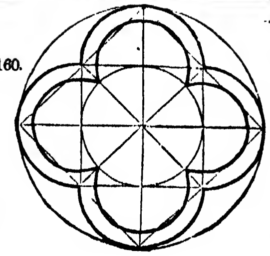


Fig. 160.

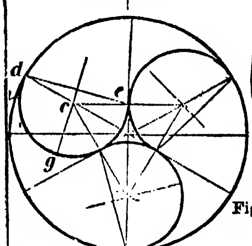


Fig. 149.

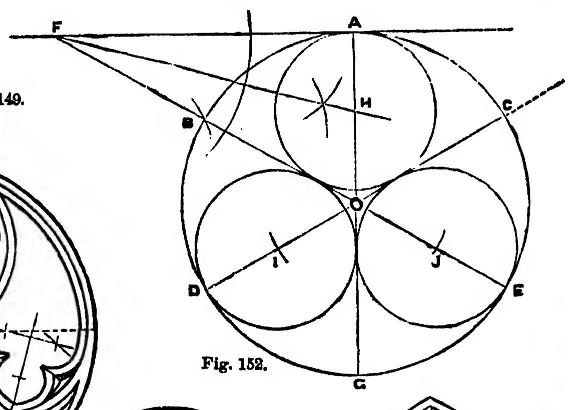


Fig. 152.

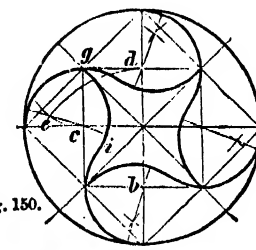


Fig. 150.

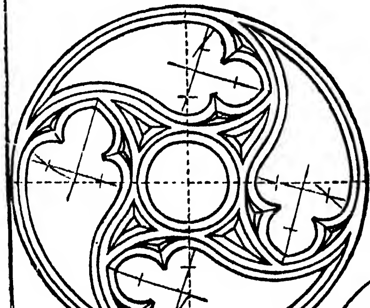


Fig. 153.

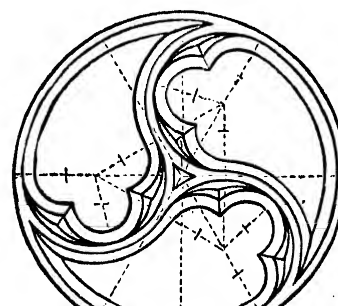


Fig. 151.

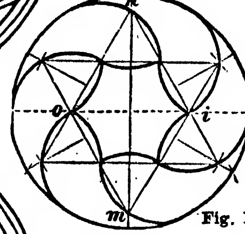


Fig. 154.

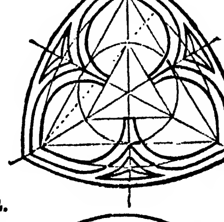


Fig. 157.

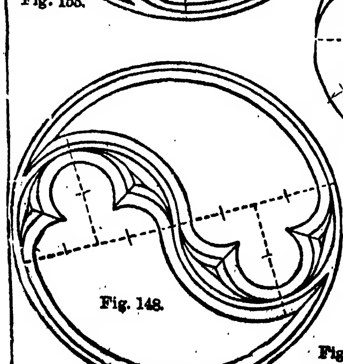


Fig. 148.

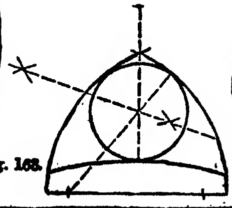


Fig. 163.

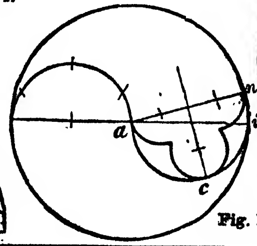


Fig. 147.

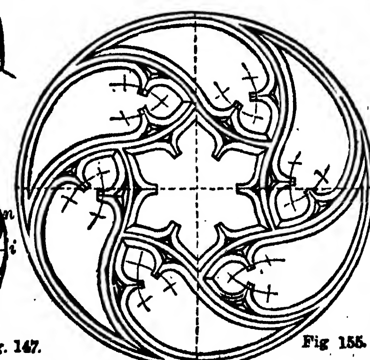


Fig 155.

Make $m\,r$ equal to $m\,o$.

From o and r, with radius $o\,r$, describe arcs intersecting each other in i: extend these until they meet the curve p in n and a.

The foliation and completion, as per Fig. 159, will now be found simple.

Fig. 160 is a quatrefoil, and Fig. 161 a cinquefoil, the construction of which has been fully described in "Practical Geometry applied to Linear Drawing" (Figs. 26 and 41).

Fig. 162 is given as a closing illustration of panel tracery; and it is hoped that, with the instructions already given, and the elementary figures 163 and 164, the student will be able to draw this example without further aid.

We shall in the next number commence a series of lessons in Drawing for machinists and engineers.

ELECTRICAL ENGINEERING.—:

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PRIMARY BATTERIES.

Class III.

The characteristic feature of the cells in this section consists of the fact that the negative element is surrounded by some strongly oxidising substance—usually in the liquid form—which unites with the hydrogen bubbles as fast as they are evolved by the action of the cell and thus preserves the negative element free from the film of hydrogen which would otherwise have been formed on it. The substances most commonly used for this purpose are nitric acid, manganese dioxide, bichromate of potash, etc., all of which possess a large supply of oxygen with which they easily part. The oxidising liquids tend to unite with the zinc (or positive element) even when the cell is not supposed to be working, and it therefore becomes necessary to construct the cell so as to be made of two reservoirs, one of which contains the true aliment and the positive element, whilst the other—which is usually contained in the first and is made of some porous substance—contains the oxidising liquid and the negative element. These oxidising liquids will also attack copper, hence the negative element must be one of the metals which possess a low heat-value. The metals most in use are platinum and carbon.

GROVE'S CELL.

One of the most convenient forms of this cell is that shown in Fig. 16. The positive element is a sheet of thoroughly amalgamated zinc Z Z bent into the form of a U; in the bend is placed the porous pot which contains as the negative element a sheet of platinum P immersed in the strongest nitric acid, which acts as the oxidising agent. The zinc is immersed in an aliment consisting of a solution of one part of sulphuric acid in ten of water (by volume).

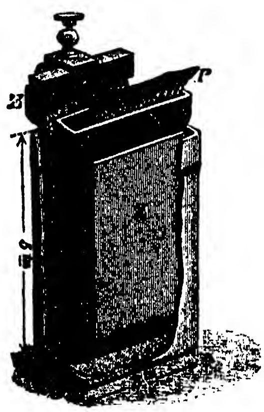


Fig. 16.—GROVE'S CELL.

The E.M.F. of this cell is high, about 1·9 volts, and its resistance extremely low—in a cell with the dimensions given in Fig. 16 it is about ·2 ohms. It can therefore be used to give a fairly constant and powerful current. It is perfectly free from polarisation as long as the nitric acid is strong, but the action of the cell continually weakens this acid by diluting it with water, thus reducing the E.M.F. and increasing the resistance—effects which are also augmented by the sulphuric acid being changed into sulphate of zinc. The most serious objection to the general use of this cell is the fact that peroxide of nitrogen is given off from it in the form of dark-red fumes of a most objectionable and unhealthy nature.

The action which takes place may be expressed in chemical language by the equation :—

Before sending the current:

$Zn + H_2SO_4$ *Zinc Sulphuric acid*	$2(HNO_3) + Pt$ *Nitric acid Platinum*

After sending the current:

$ZnSO_4$ *Sulphate of zinc*	$2(H_2O) + N_2O_4 +$ *Water Peroxide of nitrogen Platinum*

CELL.

This cell differs from the Grove in one particular only: the expensive platinum is replaced by a piece of hard retort carbon C. The usual form in which the cell is made is that shown in Fig. 17, the zinc being in the form of a split cylinder Zn. The first cost of this cell is considerably less than that of the Grove, but it uses more acid under ordinary working circum-

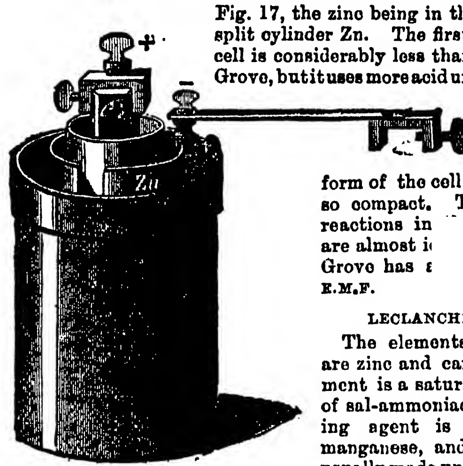


Fig. 17.—BUNSEN'S CELL.

form of the cell is not nearly so compact. The chemical reactions in are almost i Grove has a E.M.F.

LECLANCHÉ CELL.

The elements in this cell are zinc and carbon, the aliment is a saturated solution of sal-ammoniac, the oxidising agent is peroxide of manganese, and the cell is usually made up as in Fig. 18. The zinc rod which is shown to the left of the diagram should be thoroughly amalgamated. Peroxide of manganese is a solid granular substance which slowly gives up its oxygen at the ordinary temperature. As used in the Leclanché cell it is mixed with carbon—both being in the state of small lumps, not in the form of powders—and packed round

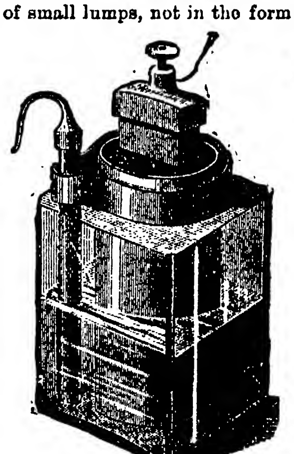


Fig. 18.—LECLANCHÉ CELL.

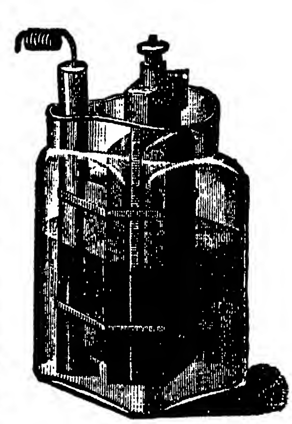


Fig. 19.—CONGLOMERATE FORM OF LECLANCHÉ CELL.

a carbon stick in a porous pot; the top of this pot is then closed with pitch, allowing only a small hole through which a little liquid can be run in when necessary. The porous pot is thus only a mechanical means used for keeping the negative element in contact with the oxidising agent.

In the more modern form of this cell the porous pot is dispensed with, the carbon and manganese being moulded into slabs (under pressure at a high temperature) which can be strapped on to the carbon by rings of caoutchouc, which also hold in position the zinc rod which is separated from the slab by a wooden insulator. This arrangement is shown in Fig 19.

When this cell is working it supplies a fairly strong current, but only for a short time, as it quickly polarises; if it is then allowed to rest it quickly recovers its original E.M.F., which is about 1·45 volts. It requires little if any attention after having been once set up, and will work satisfactorily on intermittent work—such as the ringing of a bell—for years. Care should be taken that the water which may evaporate from it should be renewed at intervals.

AGRICULTURAL DRAINAGE AND IRRIGATION.—V.

By J. Wrightson, Professor of Agriculture, Royal School of Mines.

MOLE PLOUGH—DRAINING TRENCH—DRAINING TOOLS, ETC.

In the last lesson we considered two methods of draining land, associated with the names of Elkington and Smith, of Deanstone, and concluded by giving a brief sketch of the materials used in forming underground channels. Such materials are, however, not always necessary, as it is possible to ensure a sufficient channel for water without their introduction, and also, in some cases, to dry land by open ditches. The last method of drainage need not detain us. Were we thoroughly to discuss it, we should be led into a very wide subject, embracing the surface drainage of upland pastures, the drainage of woodlands, where underground channels are not practicable, owing to the far-searching and insinuating character of the roots, and into the whole question of reclaiming marshes and fenny tracts. Under all these circumstances open ditches are used, and are occasionally of such magnitude as to resemble rivers and canals rather than ditches. Steam power is in such cases brought into requisition where the natural fall of the land is not sufficient to ensure an outfall, and the work assumes a magnitude requiring great engineering skill and a large expenditure of labour and capital. We must leave the consideration of such enterprises from sheer want of space, and restrict ourselves to more ordinary drainage operations.

With reference to the formation of underground channels without the use of tiles, stones, or any other material, two practices prevail. First, we have the *mole plough* forcing its way through a tenacious clay, and leaving a hollow channel like the path of the animal after which it is named. Secondly, we have the drainage of peat, effected by leaving a space at the bottom of a trench.

Draining by means of the "mole plough" is principally used in pastures resting upon a tenacious soil. It may also be employed as a means of drying arable land of similar character; but owing to the fact that such draining is necessarily somewhat shallow, and that arable soils are subjected to considerable pressure from the passage over them of horses and tillage implements, it follows that in their case a deeper and more permanent system is desirable.

Cheapness is the principal inducement for undertaking this work, the total cost being from £1 to £1 8s. per acre. The operation is effected by what may be termed a plough furnished with a stout coulter. This coulter, which is let down into the ground to the required depth, say thirty to thirty-two inches, is terminated by a conical or egg-formed piece of iron. The coulter cuts through the soil, and, after the passage of the implement, the earth again closes together, leaving the open channel, at the above-mentioned depth, caused by the passage of the "mole." The implement may be drawn by steam power, or by a wire rope wound around a capstan, on the headland.

Peat when drained is always liable to sink. Thus, at the November meeting of the Farmers' Club (1870), Mr. A. S. Ruston, of Aylesby House, Chatteris, informed his audience that the surface of Whittlesea Mere is seven feet lower than it was eighteen years before, when the drainage works were begun; and that "in the 'Middle Level,' on all our old-drained lands, we find the subsidence is still going on at the rate of an inch per year." While such a change of level is taking place, it would be unwise to adopt pipe-draining at the usual depths, as the lowering of the surface would subject the drains to injury from the treading of horses. The following plan is therefore used:—A trench is dug, thirty inches deep and twelve inches wide at the bottom. A narrow grafting tool (Fig. 4) is now used to deepen the trench, in such a manner as to leave shoulders on each side of the deepened portion. This is made plain by reference to Fig. 5. The sod taken from the surface is made to rest upon the shoulders just mentioned, and thus a hollow space is left as a drain. The trench is now filled up, and the work is complete (Fig. 5). In other cases, artificial channels are cut out of the substance of the peat by a tool constructed so as to form semi-cylinders of peat, which, when applied together and laid at the bottom of a trench, make a fair drain.

We have in the next place to consider the work of drainage as carried out upon the principles laid down by Mr. Smith of Deanstone. The tools with which the work is performed are worthy of consideration, and after briefly describing them we shall pass on to the consideration of the work itself. A line for marking off the work will be the first requisite in carrying out drainage work. The drainer will also require an ordinary spade (Fig. 7), which need not be described. The remaining tools for making the trench consist of two grafting tools (Figs. 4, 6). These are so designed as to economise the amount of ground removed to the greatest possible extent. A glance at the sketches in the next page will show how the successive use of the spade and grafting tools must form a narrow trench, gradually decreasing in width with the breadth of the implements, until it is about four inches wide at the bottom. A shovel for paring and smoothing the sides (Fig. 7), a pickaxe for removing land-fast stones or cutting through rock, a "swan-necked" shovel for removing small fragments of earth and levelling the bottom of the trench (Fig. 8), a pipe-layer or wooden shaft, with a piece of iron at its extremity turned at right angles to the direction of its length (Fig. 9), a spirit-level, a drain-gauge for testing the depth of the trench, and a few boards and struts to support the sides of the trench where the ground happens to be of a very soft character. Such will be the most necessary tools with which to start the work of drainage.

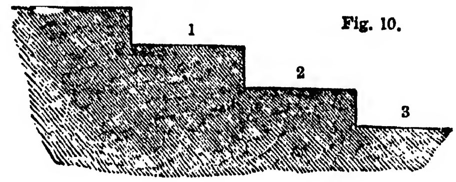


Fig. 10.

We have now explained the benefits of the drainer's art, discussed the water economy of the soil, the best materials for constructing underground channels, and the work-tools required for carrying out the necessary operations. We proceed to the practice, first asking, How can we determine whether or not a field requires draining? Indications are numerous, both in the case of arable and of pasture lands. In the case of the former, wetness is indicated by the difficulty of working the soil for considerable periods after heavy rains have fallen. The ground cuts, or turns over from the plough in compact slices, whereas in contiguous and drained soils of similar quality the furrow is more friable, crumbling down after the passage of the plough. The undrained farm, therefore, cannot compete with its drier neighbour in the growth of root-crops, to which a fine tilth is absolutely necessary. Snow, too, has been observed to lie sooner and longer on undrained than on dry soils, owing to the difference in temperature between the two. When the drying March winds sweep over the country, the dry land speedily becomes white and dusty, while wet land keeps its black wintry colour, and continues uninviting to the sower.

Wet spots on hill-sides are indicated in the same way, and these spots may be identified all through summer by stunted herbage, deficient ears, and blighted grain. In the case of pastures, wetness is shown by sponginess under foot and a peculiar bleached appearance in the spring, when more favoured pastures are assuming a bright-green colour. The presence of sedges, rushes, and mosses all point in the same direction, and show that drainage is necessary. Accompanying these appearances in the land and herbage is a defective state of health in the live stock, and the prevalence of "quarter ill" among cattle and rot among sheep. Having then supposed a farm exhibiting such indications, it is high time to relieve it of its superabundance of water.

The first thing to be secured is a good outfall. This will be

fixed upon in accordance with the slope of the ground and the means of obtaining egress for the water. We assume the existence of a suitable beck, ditch, or rivulet sufficient for our purpose, and endeavour to select a sound portion of the bank happily placed for receiving the contents of our main-drain. This follows the line of the field's greatest depression. The furrow-drains flow into it, either on one or both sides, according to the contour of the ground. Where the slope of a field is evidently in a certain direction, all this is easily arranged; but where the fall is slight the eye cannot be trusted, and the "level" must be used. One yard in every 220 is an ample fall.* Having decided on the direction of the main and furrow drains, our next business will be to distribute tiles in small heaps at intervals along their proposed paths. Next, the work is commenced at the outfall by marking out with a line, and in the case of pasture land carefully removing the sod, and depositing it on one side. In arable land, the track of the drains may be marked out by the plough. Whichever method be decided upon, the cultivated soil or sod must be deposited upon one side, and the lower and less important soil upon the opposite side. The work commences at the outfall, represented in Fig. 10. One man steadily works backward, taking out the first spade's depth. A second labourer then commences at the outfall, standing in the trench made by the first man, and also working backwards, using the first grafting tool. A third man now commences at the outfall, with the bottoming tool, and taking out the last graff. Thus the work progresses from the outfall against the slope of the land, and in this way a clean-cut trench of uniform depth and width is excavated, the bottom being made smooth and level with the scoop or swan-necked shovel.

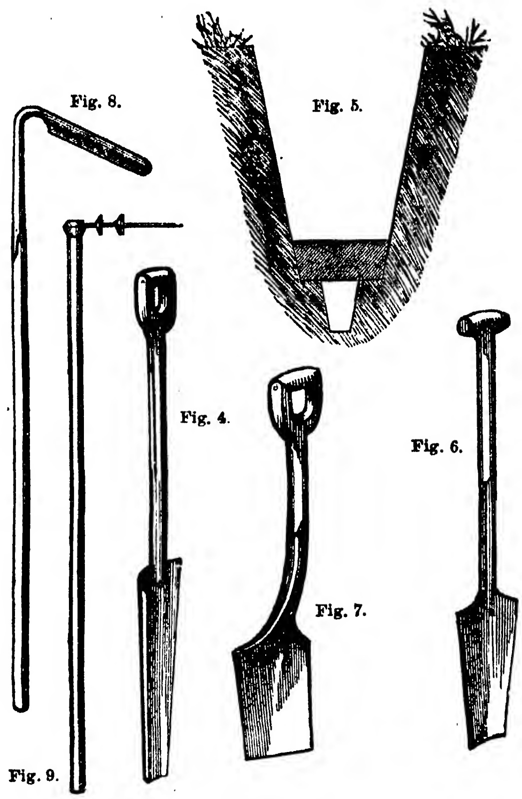


Fig. 8. Fig. 5. Fig. 4. Fig. 6. Fig. 7. Fig. 9.

The depth of the drains, and the distance between the furrow-drains, are important questions in carrying out the work. With reference to depth, we recommend $3\frac{1}{2}$ to 4 feet as sufficient under ordinary circumstances. It is, however, not uncommon to find the strata of a field so arranged that a great advantage is secured by sinking the drains somewhat deeper. Mr. Girdwood writes as follows upon depth and distances apart of drains:—"I find it necessary to drain from eight to ten yards apart on the Weald and Oxford clays; at from ten to twelve yards on the clays of the Red Sandstone, where there is a uniform so-called homogeneous clay subsoil. In such cases the usual depth I employ is 4 feet for the minor drains, and 4 feet 3 inches for the mains. . . . In some of the gypseous clays in Derbyshire and Staffordshire I have gone to great depths. In one case, at Sudbury, the seat of Lord Vernon, I have drained about forty acres at a depth of from eight to eleven feet. The drains are sixty-six yards apart, and have been perfectly successful. I dug down at a dry time, finding no great rush of water till I got to about eight feet. It then began to flow, and at ten feet it rushed in with such force that the men had to be hauled up." Mr. Stephens, in his "Book of the Farm," says—"With regard to the distance between drains in a partially impervious subsoil, fifteen feet is as great a distance as a three-feet drain can be expected to draw, and in some cases I have no doubt that a four-feet one will be required. In more porous matter a three-feet drain will probably draw twenty feet with as great, if not greater effect; and in the case of a mouldy deep soil, resting on an impervious subsoil—which is not an uncommon combination of soils in the turnip districts of this country—a drain passing through the mould, and resting perhaps three or four inches in the impervious clay—which may altogether make it four feet deep—will draw, I have no doubt, a distance of thirty feet. More than thirty feet, I would feel exceedingly reluctant to recommend drains being made, unless the circumstances were remarkable." Furrow-drains, it is maintained, should not be more than 200 yards long; and if the slope down which they are brought is of much greater length, it will be advisable to break the distance—by running a main-drain across the line of slope, so as to carry off half the water—and to complete the drainage of the slope with a new series of furrow-drains.

The direction of the main-drains has been sufficiently indicated. That of the furrow-drains ought, as a rule, to follow the *line of greatest slope*. Such is the plan enforced by Government Inspectors of Drainage where the work is assisted by Government grants. In other cases, where the owner has full liberty to follow any plan that pleases him, it may be worth while to deviate slightly from this general rule when the old watercourses diverge from the line of greatest slope. A ruthless disregard of the path of old, long-used furrows has often been followed with mischievous consequences. There are, indeed, drainers who advocate crossing the line of greatest slope; but it may be readily shown that for a drain to exert its action equally on both sides, only one direction is possible—that of greatest slope.

Draining is a winter operation, and the work may be seriously impeded by heavy falls of rain or snow. It is for this reason that the work must be completed as it proceeds. No sooner is the trench opened than it must be prepared for the reception of the tile, by levelling the bottom, and making sure that water will be able to run down the trench without interruption. A practical mode of testing this is to empty a bucket of water at the head of the trench, and watch its course. Any small obstruction or hollow place may then be dealt with so as to ensure a perfect fall. The next point is to lay the tile. This work is usually committed to a superior man, or the foreman of the work, who, while he lays the pipes, must see that the trench is satisfactory in depth and levelness. Tiles must be laid and covered in up to the point where the work ceases, and the last tile laid should be stopped with a wisp of straw to prevent the entrance of anything which may obstruct the passage. Every tile should be perfect, and unworthy ones ought to be thrown aside. In the laying of main-drains, tiles three inches in diameter are in general use, and two-inch tiles are sufficient for furrow-drains. The furrow-drains are constructed upon the same principle as the mains, care being taken that the junction with the mains is secure and perfect. No two furrow-drains should open into the main exactly opposite to each other, as such a combination would be a cause of weakness in the main channel. Main-drains also should be three inches deeper than the furrow-channels, so that a rapid fall may be given at the confluence of the two.

* "Water will flow in large rivers with a fall of three inches in a mile."—*Robert Beart, Journal of the Royal Agricultural Society* (Vol. IV.).

PRINCIPLES OF DESIGN.—VI.

By Christopher Dresser, Ph.D., F.L.S., etc.

HARMONIES AND CONTRASTS OF COLOUR (*continued*).

In my last chapter we commenced the consideration of the harmonies and contrasts of colour, and set forth the laws governing its application to objects by axiomic propositions; and the principles taught in these axioms were illustrated diagrammatically.

With the view of continuing this diagrammatic form of illustration, and of impressing upon the mind the statements made in my former chapter, and with the further view of familiarising my readers with this mode of study in the hope that they may apply it to my essays on the various manufactures, I shall make manifest the quantities in which the various colours harmonise: thus:—

Blue.	*Red.*	*Yellow.*
O O O O O O O O	O O O O O	O O O

Blue		*Orange.*
O O O O O O O O	harmonises with	O O O O O O O O
Red		*Green.*
O O O O O	harmonises with	O O O O O O O O O O O
Yellow		*Purple.*
O O O	harmonises with	O O O O O O O O O O O O O
Purple		*Citrine.*
O O O O O O O O O O O O O	harmonises with	O O O O O O O O O O O O O O O O O O O
Green		*Russet.*
O O O O O O O O O O O	harmonises with	O O O O O O O O O O O O O O O O O O O O O
Orange		*Olive.*
O O O O O O O O	harmonises with	O O O O O O O O O O O O O O O O O O O O O O O O

To those who are about to practise ornamentation, it is very important that they should have in the mind's eye a tolerably accurate idea of the relative quantities of the colours necessary to harmony, even where the colours are considered as existing in a state of absolute purity. We have rarely, however, to use the brightest blues, reds, and yellows which pigments furnish, and even these are but poor representatives of the potent colours of light as seen in the rainbow, and with the agency of the prism; nevertheless, a knowledge of the quantities in which these pure colours harmonise is very desirable. The proportions in which we have stated that colours perfectly harmonise, and in which the primary colours combine to form the secondaries, and the secondaries the tertiaries, are given in respect to the colours of light, and not of pigments or paints, which, as we have just said, are more or less base representatives of the pure colours of light. Yet certain pigments may, for our purpose, be regarded as representing pure colours. Thus, the purest real ultramarine we shall regard as blue (cobalt is rather green, that is, it has a little yellow in it; and the French and German ultramarines are generally rather purple, or have a little red in them, yet the best of these latter is a very fine colour), the purest French carmine as red (common carmine is frequently rather crimson, that is, has blue in it, or rather scarlet having yellow in it; vermilion is much too yellow), and lemon chrome as yellow (the chrome selected must be without any green shade, and without any orange shade, however slight); and these pigments will be found to represent the colours of the prism as nearly as any that can be found. I would recommend the learner to get a small quantity of these colours in their powder form, substituting the best pale German ultramarine for real ultramarine, as the latter is of such a high price,* and to fill the various circles of our diagrams, which represent the primary colours, with these pigments, mixing them with a little dissolved gum arabic and water. The secondary colours will be fairly represented by pale-green lake, often called drop-green, by orange-chrome—that of about the colour of a ripe, rather deep-coloured, orange rind—and the purple by the admixture of pale German ultramarine and crimson lake, in about equal proportions, with a little white to bring it to the same depth as the green. I cannot name any pigments which would well represent the tertiary colours. Citrine is about the colour of candied *lemon* peel; olive about the colour of candied citron peel, and russet is often seen on the skin of certain apples called "russet apples," in the form of a slight roughness; but this russet is in many cases not quite sufficiently red to represent the colour bearing the same name. Iron rust is rather too yellow. This colour should bear the same relation to red that the candied lemon-peel does to yellow.

If the student will try carefully to realise these colours, and will fill up the circles in our diagrams with them, he will thereby be much assisted in his studies; but it will be still better if he prepare fresh diagrams on a larger scale, and use squares instead of circles. I should recommend, and that I do strongly, that the student work out all the diagrams which we have suggested on a tolerably large scale, using the colours where I have used words. I should also advise him to do an ornament, say in red on a gold ground, and outline this red ornament with a deeper red; to do a gold ornament on a coloured ground, and outline it with black; and indeed to carefully work out an ornamental illustration of our propositions, Nos. 24, 25, 26, and 27, and to keep these before him till he is so impressed by them as to *feel* the principle which they set forth. This should be done on a large scale in all our designing-rooms and art-workshops.

As we shall have to refer to colours by naming pigments, and as I am constantly asked what pigments I employ, I shall enumerate the paints in my colour-box; but I shall place a dagger † against those which I have in my private box, and which I do not supply in my offices; but these I seldom use. Of yellows I have king's yellow† (not a permanent colour), very pale chrome,† lemon chrome (about the colour of a ripe lemon), middle chrome (half-way between the lemon and orange chrome), orange chrome (about the colour of the rind of a ripe orange), yellow lake,† Indian yellow.† Of reds—vermilion, carmine, crimson lake. Of blues—cobalt,† German ultramarine, both deep and pale, Antwerp blue, indigo. Of greens—emerald, green-lake, pale and deep. Of browns—raw Turkey umber, vandyke, Venetian red, purple-brown, brown-lake. Besides these I have what is called celestial blue, which is a very pure and intense turquoise, vegetable black, flake white, and gold bronze.

There are certain facts connected with the mixing of colours which must never be lost sight of; thus, while the colours of light co-mingle without any deterioration, or loss of brilliancy, pigments or paints will not do so, but by admixture tend to destroy one another. This takes place only to a small extent

* Real ultramarine is sold at £8 per ounce. The best imitation, or German ultramarine, is procurable at any oil-shop at about 3s. to 4s. per pound. The best carmine should be procurable at 6s. per ounce, but artists' colourmen often charge £1 1s, owing to the small demand for this pigment. The best chrome yellow (this is kept in many shades) is about 1s. 6d per pound.

when but two primary colours are combined; but if any of the third primary enters into the composition of a tint, a decided deterioration, or loss of intensity, occurs.

For this reason we employ many pigments, so as to get as little mixing of colours as we can. But there is another reason why the great admixture of colours is undesirable. Colours are chemical agents, and in some cases the various pigments act chemically on one another. Of all colours yellows suffer most by admixture with other colours; but this is accounted for by their delicacy and purity. For this reason I use a greater variety of yellow pigments than of red or blue.

Were it possible to procure three pigments devoid of chemical affinities, and each of the same physical constitution, as of equal degrees of transparency or opacity, the one truly representing the blue of light, another the red, and another the yellow, we should need no others, for of these we could form all other colours; but as no pigments come even near to the fulfilment of these conditions, we have to employ roundabout and clumsy methods of arriving at our ends.

Were I inquiring into the laws of colour with a view to scientific ends, I could here point out a number of most interesting facts; but while I must not do so, I am happy to say that Professor Church has contributed a series of papers to THE TECHNICAL EDUCATOR, taking the scientific view of colour; and I would urge upon my readers the desirability of studying these contributions, for there they will find the explanation of facts which I can only mention.

I hesitate to proceed, lest I should not have made my meaning sufficiently clear respecting points on which I have touched; and before I do so I think that it will be safer if I extend my remarks respecting certain statements; for there is always the fear of supposing that, because one happens to be familiar with a certain subject, others, who have never before thought on the matter, must at once catch his meaning, even if given almost in the bare form of a hint; and it is certainly safer to err on the side of excessive elucidation than on that of poverty of explanation.

There is one statement which I made in my last paper that, perhaps, needs a little elucidation, although the careful student may have seen the reason of my statement. I said that purple harmonised with citrine, green with russet, and orange with olive. I might have expressed it (and many would have done so) thus:—The complement of citrine is purple, the complement of russet is green, and the complement of olive is orange. A colour which is complementary to any other is that which, with it, completes the presence of the three primary colours: thus green is the complement of red, and red of green, for each, together with the colour to which it is the complement, completes the presence of the three colours. But in order to a harmony, the complement must be made up in certain proportions. Let us now refer to our second diagrammatic table in my last article, and we there see that citrine is formed of two equivalents of yellow and only one equivalent of red and of blue. Now, in order to a harmony, each primary should be present in two equivalents, as one is present in this quantity—*i.e.*, the yellow. One equivalent of blue and one of red (both of which are wanting in the citrine) form purple; hence purple is the complement of citrine, or the colour that with it produces a harmony. In russet one equivalent of blue and one of yellow are wanting, and these in combination are green—green, then, is the complement of russet. And in olive one equivalent of red and one of yellow are wanting—red and yellow form orange, hence orange is the complement of olive.

I have spoken of all colours as of full intensity and purity, but we have to deal also with other conditions. All colours may be darkened by black, when *shades* are produced; or reduced by white, when *tints* are produced. Besides these alterations in intensity, a portion of one colour may be added to another. Thus, if a small portion of blue be mingled with red, the red becomes a crimson or blue-red; or if a small portion of yellow be added to the red, the latter becomes a scarlet or yellow-red. In like manner, when yellow is in excess in a green, we have a yellow-green; or when blue is in excess, a blue-green; and so with the other colours. Such alterations produce *hues* of colour.

We now come to the subtleties of harmony. Thus, if we have a yellow-red or scarlet—a red with yellow in it—the green that will harmonise with it will be a blue-green; or if we have a blue-red, a crimson—a red with blue in it—the green that will harmonise with it will be a yellow-green. This is obvious, for the following reasons:—Let us suppose a red represented by the equivalent number, five, with one part of blue added to it, thus causing it to be a blue-red or crimson. Were the red pure, there should be eleven parts of green as a complement to the five of red, of which green eight parts would be blue and three yellow; but the blue-red occurs in six parts, one of which is blue—there are, then, but seven parts of blue remaining in the equivalent quantity to combine with the three of yellow, one being already used; hence the green formed is a yellow-green, one of the equivalents of blue necessary to the formation of a true green being already in combination with the red, and thus absent from the green.

The same reasoning will apply to the scarlet-red and blue-green, and, indeed, to all similar cases; but to take the case of the crimson-red and yellow-green, as just given, and carry it a stage further, we might add two parts (out of the eight) of blue to the red, and make it more blue, and then form the complementary green of six parts of blue and three of yellow, and thus make it more yellow. Or we may go farther still, and add to the red six of the eight parts of blue, when the admixture would appear as a red-purple rather than as a blue-red, in which case the complementary green—or, rather, green-yellow—would consist of two parts of blue and three of yellow. These facts are diagrammatically expressed in the following:—

Red. OOOOO O *Blue.*	*Crimson*	harmonises with	*Yellow-Green.*	*Yellow.* OOO OOOOOOO *Blue.*

Or,

Red. OOOOO OO *Blue.*	*Blue-Crimson*	harmonises with	*Very Yellow*	*Yellow.* OOO OOOOOO *Blue.*

Or,

Red. OOOOO OOOOOO *Blue.*	*Red-Purple.*	harmonises with	*Green-Yellow.*	*Yellow.* OOO OO *Blue.*

In all these cases it will be seen that we have eight parts of blue, five of red, and three of yellow, only the mode of combination varies. This variation may occur to any extent, provided the totals of each be always the equivalent proportions.

These remarks will apply equally to hues of colour, shades, and tints, and to shades and tints of hues.

Care, and perhaps a little practice, will enable the learner to arrange colours into a number of degrees of depth, or shades, as they are generally called. (We do not here use the term as signifying pure colours darkened with black.) Ten shades of each colour differing obviously in degree of depth can readily be arranged by the experienced, the ten shades being equidistant from each other as regards depth—that is, shade 3 will be as much darker than shade 2 as shade 2 is darker than shade 1, and so on throughout the whole. Purple is a colour intermediate between blue and red. Imagine ten hues between the purple and the red, and ten more between the purple and the blue: thus we should have purple, then a slightly red purple, then a rather redder purple, then a purple still more red, and so on till we get purple-reds, and finally the pure red; and the same variations of hue at the blue side also. Imagine, further, the green having ten hues extending towards blue, and ten more stretching towards the yellow; and the orange having ten hues towards the red, and ten towards the yellow—in all cases I count the colour from which we start as one of the ten, thus:—

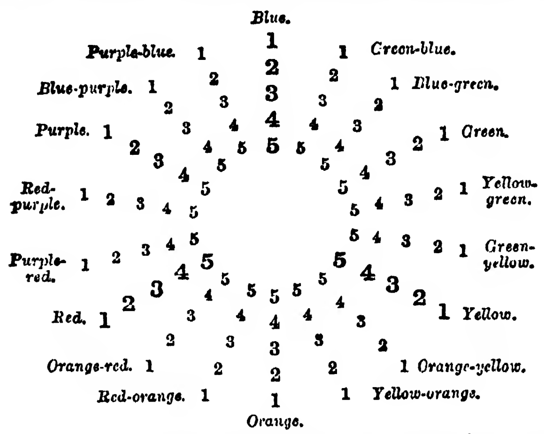
Blue.									Purple.									Red.
0	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	0

—and we shall have 54 colours and hues of colour. Of each of these 54 colours and hues imagine 10 degrees of depth, and we get 540 colours, hues, tints, and shades, all differing from one another to an obvious degree.

Mark this fact, that any colour, tint, hue, or shade of such a diagram has its complement in one other of the colours, tints,

hues, or shades of the diagram, and that only two of this series of 540 are complementary to each other; thus, if you fix on any one colour of the 540, there is but one colour in the whole that is complementary to it, and it is complementary to but this one other colour.

The student will do well to try and make a colour-diagram of this kind, of a simple character, say such as the following, only using pigments for my numbers; but in doing so he must exercise the utmost care, in order that he secure some degree of accuracy of tint or shade, and if he can call to his aid an experienced colourist it will be of great assistance to him.



This table is highly valuable, as it gives ninety harmonies, if carefully prepared in colour; and the preparation of such a table is the very best practice that a student can possibly have.

Let us for a moment consider this table, and suppose that we want to find the complement to some particular colour, as the third shade of red. We find the complement of this in the third shade of green opposite. If we want the complement of the second shade of orange-yellow, we find it in the second shade of blue-purple opposite, and so on. Thus we have a means of at once judging of the harmony of colours.

FORTIFICATION.—IV.

BY AN OFFICER OF THE ROYAL ENGINEERS.

TRACE OF WORKS—DEFINITIONS OF VARIOUS METHODS OF ARTILLERY ATTACK, AND MODES OF OBTAINING PROTECTION FROM THEM.

Before considering the varieties of trace suitable for works under different circumstances, it will be well to examine the ways in which artillery and musketry fire can be employed for their attack and defence, and then what defensive arrangements can be made to guard against these. Various terms are employed to express the direction, mode of firing, and special objects of artillery fire, with reference to the works attacked. Thus the terms *direct*, *oblique*, *reverse*, *enfilade*, *flanking* all express the horizontal direction of the fire; whereas *plunging*, *pitching*, *vertical*, and *ricochet* denote varieties either in the mode of firing, or the results to be attained.

The terms *direct* and *oblique* are applied to the fire of guns placed either immediately opposite or oblique to the direction of the works attacked.

Reverse fire is that which is brought to bear on the interior of a work by guns firing into it from the rear. When the guns of the assailants are so placed as to bring either a direct or oblique fire to bear on the works, they must be opposed by parapets of sufficient strength and thickness to resist them; but when protection from reverse fire is required, it becomes necessary to construct a sort of second parapet inside the work, behind the guns, which is called a *parados*.

When the enemy's guns are in prolongation of the line of work attacked, and can fire along the rear of that line, it is called *enfilade* fire. This is a very effective method of artillery attack, as any one shot may take effect on many more guns or men than it could if it merely passed directly through the parapet. To guard against this, great care should be taken in tracing a work that the prolongations of the lines of parapet are directed on to points inaccessible or beyond the range of the enemy's guns. Where this is impracticable, short earthen parapets, called *traverses*, must be built at right angles to the general line, to intercept the shot.

Ricochet fire is that in which the charge and elevation of the guns are so arranged as to cause the shot to make a number of rebounds after its first graze in the work. It is consequently often employed for enfilading purposes.

When a line of parapet is so placed that the fire from its guns passes parallel to and in front of another line, it is called a *flank*, and defends that line by a flanking fire. A glance at

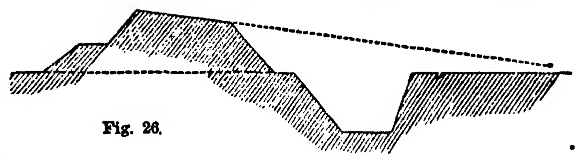


Fig. 26.

any ordinary profile (Fig. 26) will show that the ditch cannot be defended by the direct fire of the parapet behind it, and unless the ditch is defended by a flank fire from some other part of the work, the enemy might assemble in comparative safety in it before making his final assault. This defence is obtained either by means of flanks or by constructions in the ditch, and it is with reference to it that most of the varieties in the trace of works other than those dependent on the shape of the ground are made.

Vertical fire is that from mortars firing shells at an angle of 45° so as to fall almost vertically. This is the least accurate of all the artillery fire we shall have occasion to consider, but is useful for bombarding towns, closed works, etc., where great accuracy is not essential. Protection from the effects of vertical fire can only be obtained by constructing buildings, the roofs of which are of sufficient thickness to resist the fall of the shells from a great height, and their subsequent explosion. In all works intended to make a prolonged resistance to modern artillery, protection of this kind, or "bomb-proof cover" as it is called, must be largely provided. When these buildings are of a permanent nature, they are called *casemates*, and where only temporary constructions, *blindages*. As a guide to the thickness of roof necessary for this purpose, it may be well to remember that the maximum penetration of the largest spherical shells in the British service (13 inches) was found to be as follows, viz.—penetration in earth, 6 feet; in concrete or brickwork, 1 foot 6 inches.

Pitching fire is similar to ricochet, except that the shot descend at such an angle as not to rebound. It is used in the attack of works, to strike objects that are hidden from view by some intervening mass, over which the shot must pass. Escarp walls and other masonry in permanent fortifications are liable to be breached by this means, unless they are kept considerably below the direct line of fire.

Plunging fire is that from guns firing with full charges at objects on a much lower level than themselves. Owing to the considerable angle of depression of the guns the shot do not ricochet, and greater accuracy in firing is required; it is not, therefore, very efficient against troops or small moving objects, but is most effective against ships, whose guns probably cannot elevate sufficiently to reply, and whose decks, even in ironclads, are rarely invulnerable. The Russian "Wasp" battery, which did so much damage to the English ships bombarding Sebastopol, was an example of this. Undoubtedly the advantages of a commanding position are so considerable, and the difficulties of protecting the interior of a work from plunging fire are so great, that none but urgent reasons can justify works being placed in so disadvantageous a position; it must not, however, be supposed that a slight difference of level constitutes plunging fire, or that a work is necessarily untenable because it is somewhat lower than the attacking guns; for the Russian lines at Sebastopol withstood for more than a year the attack of the Allies, whose artillery was posted on a higher level than they were.

The object of almost all works being that of enclosing or protecting some particular area, it follows that few can consist of a mere straight line of parapet, and their trace or outline shape will depend—

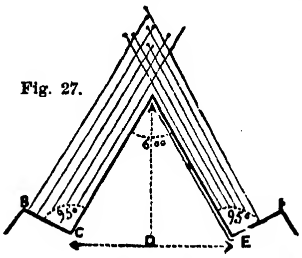
1. On the number of men they are intended to hold.
2. On the shape of the ground.
3. On the necessity for flank defence for the ditches and ground in front.

The trace will, therefore, either be a curved line or consist of a number of lines forming angles with one another. When an angle points outwards from the work it is called a *salient angle* (Fig. 27); and when it points inwards, a *re-entering angle.* The former should be as obtuse as possible, and never less than 60°.

The imaginary line bisecting a salient angle is termed the *capital.*

The distance from a flank to the furthest point of the work flanked by it, measured in the direction of the flanking fire, is called a *line of defence.* The length of this line is dependent on the weapons used, although, as the same accuracy can never be obtained from men who are being fired at as from ordinary target practice, it is made considerably less than the effective range of these arms. In field-works, therefore, the lines of defence should not, as a rule, be more than 200 yards long; and in permanent works, where the ditches are flanked by artillery, they may vary from 300 to 500 yards, so as to be within range of case and grape-shot.

Fig. 27.



C A E, salient angle; A D, capital; C E, gorge; B C E F, flanks; B C A, A E F, re-entering angles, or flanking angles, or angles of defence; C A, line of defence.

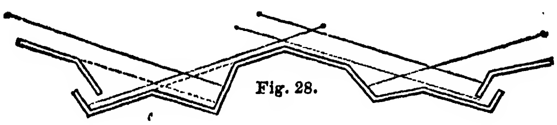


Fig. 28.

The angle between a flank and a line of defence is called the *flanking angle* or *angle of defence.* This should never be less than a right angle, lest accidentally oblique fire should wound men defending the parapet that is being flanked; and should not exceed 95°, as the fire would then become too divergent.

When the parapets of a work entirely surround the site occupied, and its garrison is consequently capable of an independent resistance, no matter on which side the attack may be made, it is called a *closed work;* and when its parapets only afford a defence in certain directions, leaving an open side or *gorge* liable to attack, it is called an *open work* (Fig. 28).

Closed works are suitable for isolated positions, and should, if possible, have their own flank defence. Open works are chiefly used as auxiliaries to other works, to afford a flank defence for the approaches to them, and are themselves defended by the flank-fire of the works in rear, which should be able to fire into their open gorges and prevent an enemy occupying them.

Both open and closed works are frequently combined so as to mutually defend one another, for the occupation of a long line or position. They are then called *lines of intrenchments.*

If a number of open works are connected by a line of parapet or obstacles, they are called *continuous lines;* and if the works are isolated and the spaces between them only defended by the fire of the collateral works or works in rear, they are called *with intervals* (Fig. 29). Closed are better than open works for this latter case, unless there is a second line of works behind the first, in which case the gorges of the open works must be closed by obstacles, to prevent the enemy, by a temporary success, getting possession of them, and dismounting the guns or doing other damage before retiring.

In permanent works an attack on the rear of the open works in connection with the fortress can rarely be made, owing to the formidable nature of the ditches that surround them

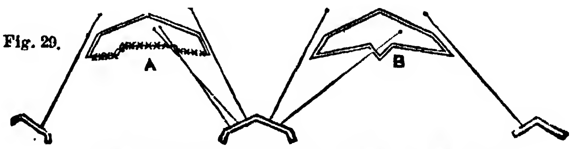
When closed works are employed in the outer line, their gorge parapets should be made so thin as not to prevent the guns of the rear-line firing into them.

The principal descriptions of open works employed in field defences are—*redans, flèches, double* or *triple redans,* and *lunettes;* and in permanent fortification more formidable works, answering the same purpose if not exactly of the same shape, are employed, called *ravelins, lunettes, horn works,* and *crown works.*

Redans, flèches, and *ravelins* are all of much the same form, and consist of two lines of parapet meeting in a salient angle.

A *redan* is a large field-work of this shape; whereas a *flèche* is a smaller work, intended merely to protect a gate or some similar small object. In Fig. 30 is shown Vauban's Redan line, consisting of redans 180 yards apart, connected by a straight line of parapet.

Fig. 29.



A, open-work gorge closed by obstacles; B, closed work.

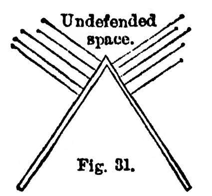


Fig. 31.

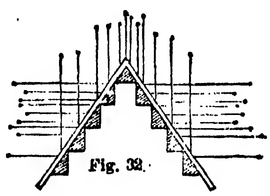


Fig. 32.

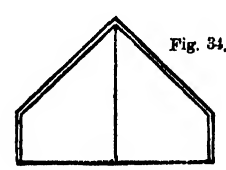


Fig. 34.

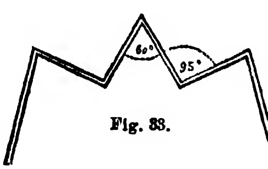


Fig. 33.

Fig. 30.

A *ravelin* is a permanent redan-shaped outwork, placed in advance of a permanent fortification to increase its defensive powers.

All these works have the defects of being liable to be enfiladed, of being open at the gorge, and of having the space in front of the salient angle badly defended. This is owing to the fact that men firing over a parapet deliver their fire at right angles, or nearly so, to the crest (Fig. 31).

This undefended space may be brought under fire by the addition of short auxiliary flanks (see Fig. 29), or by forming a short face at right angles to the capital. In some cases where the front fire of a ravelin may be much wanted, and its flank fire required in a direction at right angles to the capital, this principle may be still further applied (see Fig. 32).

A *double* or *triple redan* consists of two or three redans combined as one work (Fig. 33). In these the flank defence of the salients is provided for, but the outer faces on either side are unflanked. A *lunette* is a redan with two extra faces parallel to the capital (Fig. 34). It is useful as an advanced outwork, but has all the defects of other open works.

Open works are specially adapted for the protection of bridges or other positions where they cannot be attacked in rear. They are then called *têtes du pont* or bridge-heads.

BUILDING CONSTRUCTION.—VIII.

ARCHES (*continued*).

THE *semi-circular arch* was the kind of arch principally used by the Romans, who employed it largely in their aqueducts and triumphal arches. Other forms, however, are mentioned by some writers as having been employed by the ancients. In the Middle Ages forms still different to those already in use were generally introduced. Thus we have—

The *stilted arch*, which it is scarcely necessary to say is but an adaptation of the semi-circular, the springing being raised above the capitals of the columns. The illustration below (Fig. 55), copied from Mr. Owen Jones's admirable handbook to the Alhambra Court of the Crystal Palace, will afford the student a good example of this species of arch.

Next we have the *horseshoe arch*, also used in, and almost entirely restricted to, the Arabian style of architecture. In this form of arch the curve is carried below the line of centre or centres; for in some cases the arch is struck from *one* centre,

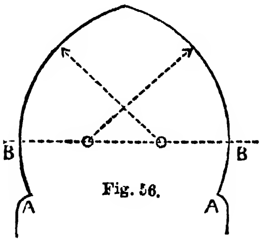


Fig. 56.

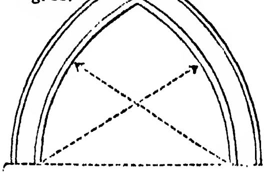


Fig. 58.

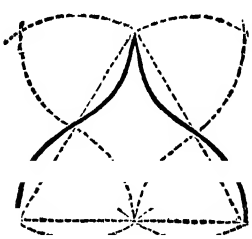


Fig. 59.

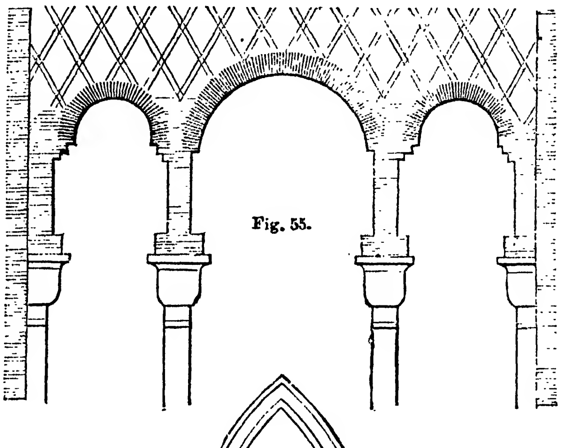


Fig. 55.

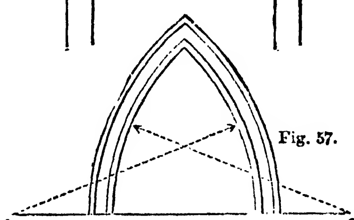


Fig. 57.

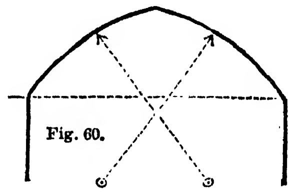


Fig. 60.

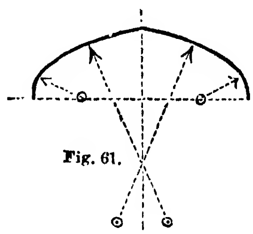


Fig. 61.

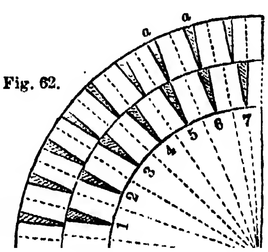


Fig. 62.

and in others from two, as in Fig. 56.

Now it must not be supposed that the real bearing of the arch is at the imposts, A, A; for if this were really so, it must be seen that any weight or pressure on the crown of the arch would cause it to break at B; but the fact is simply that the *real* bearings of the arch are at B, B, and the prolongation of the arch beyond these points is merely a matter of form and has no structural significancy. The horse-shoe arch belongs especially to the Mahometan architecture, from its having originated with that creed, and from its having been used exclusively by its followers.

Next in point of time, but by far the most graceful in form, is the *pointed arch*, which is essentially the mediæval (or middle age) style, and is capable of almost endless variety. The origin of this form of arch has been the subject of much antiquarian discussion; but it is certain, that although the pointed arch was first generally used in the architecture of the Middle Ages, recent discoveries have shown that it was used many centuries previously in Assyria.

The greater or less acuteness of the pointed arch depends on the position of the centres from which the flanks are struck.

Thus the *lancet arch* (Fig. 57) is constructed by placing the centres C, C outside the span, but still on the same line with the imposts. This form of arch was first used in the Gothic, and as a rule indicates the style called "Early English," which prevailed in this country from about 1189 until 1307.

Fig. 58 is the *equilateral arch*, the radius with which the arcs are struck being equal to the span of the arch, and the centres being the imposts; and thus, the crown and the imposts being united, an equilateral triangle is formed. This form was principally used in the "Decorated" period of Gothic architecture, from about 1307 until about 1390, at which time the *ogee arch* (Fig. 59) was also occasionally used.

At a later date, during the existence of the "Perpendicular" style of Gothic architecture—viz., from the close of the fourteenth century to about 1630—we find various forms of arch introduced, such as the *segmental* (Fig. 60), formed of segments of two circles, the centres of which are placed below the springing; and still later on we find the *Tudor* or four-centred arch (Fig. 61), in which two of the centres are on the springing and two below it. The arches at the later period of this style became flatter and flatter, and this forms one of the features of Debased Gothic, when the beautiful and graceful forms of that style gradually decayed, and for a time were lost. Happily, in the present century there has been a gradual and spirited revival of the Gothic style, and works are now being produced which bid fair to rival in beauty of form and in principles of construction the marvellous buildings of the Middle Ages. As the principles of Gothic Architecture will form the subject of another series of lessons, further description is here unnecessary.

We now return to the constructive principles of arches, and these may be conveniently treated of under the separate heads of brick arches and those constructed of stone, the main principles being the same—viz., that the bricks or stones composing the arch must be so placed that they act as wedges. In stone arches, this is accomplished by cutting the stones into the exact forms required. In bricks, they must either be "gauged," that is, rubbed or cut to the shape required, or the difference must be made up by mortar; the skill of the workman being in this case displayed by his so bonding his courses that the shrinking may be equally distributed, and that when the necessary settlement is arrived at, the structure may be found perfectly safe and strong.

Arches in brickwork are *plain*, *rough*, and *cut* or *gauged*.

Plain arches are built of uncut bricks, and these being blocks of equal thickness, must be "made out" with mortar (Fig. 62, *a a*); that is, the difference between the intrados and the extrados must

be filled in with mortar or cement. Thus, in building such an arch, the bricks at the inner line should all but touch, and the centering (the wooden framework upon which the arch is temporarily built) should not be struck (or removed) until the arch has settled or the cement perfectly hardened. The cement used should be of greater consistency than for general purposes. In consequence of the unavoidable defect in plain brick arches—viz., that the bricks are not in themselves wedge-like in form, but are kept apart at the top by a matter liable to shrink—it is advisable in extensive and continuous works, such as tunnels, sewers, vaults, etc., to make them of thin independent rings of half-brick or one-brick thick—that is, a 9-inch arch should be in two half-brick arches, as is shown in the illustration (Fig. 62), and an 18-inch arch should be formed of rings consisting of alternate whole and half-bricks, the bricks being put in where they come naturally, as where three, four, or more bricks of the inner ring cut in with four, five, or more of the outer ring; but by half-bricks we do not, in this case, mean bricks *cut* into halves, but merely laid on their edge, as *headers*, so as to be *half-brick high*. Each arch thus becomes bonded in itself with headers and stretchers, as in a brick wall.

Rough arches are those in which the bricks are roughly cut with an axe to a wedge form, and are used over openings, such as doors and windows, when the work is to be plastered on the outside, or in plain back-fronts, outhouses, garden gates, etc.; when, however, they are generally neatly finished off with what is called a "tuck joint." This consists in marking the divisions by a neatly-raised line of fine white plaster, having previously pressed a blue mortar into the joints.

Pointing is of two kinds, *tuck*, as above, and *flat*. This last consists in first raking out the mortar in front of the joints, and filling in with mortar, on which the line is then marked with the edge of the trowel.

Semi-circular and elliptical arches, when large, are generally formed of uncut bricks; but those composed of small segments of circles are either cut or axed. These are sometimes called *scheme arches*. Very flat arches are known by the name of "camber," from the French word *cambrer*, to round like an arch.

Gauged arches are formed of bricks which are cut and rubbed to gauges or moulds, according to a full-sized drawing of half an arch. Gauged arches are, of course, the neatest in appearance, and are therefore used in the fronts of houses.

When the arches are semi-circular, the bricks will all be of one shape, and therefore, if the number of arches renders it worth while, the bricks may be all moulded; that is, made specially of the exact size and form required. The arches over windows in fronts of houses are frequently *straight*. Such a window with a diagram (Fig. 63) will be shown in the next lesson. The outer slant line of the arch is called the *skew-back*, and, as a rule, the skew-backs of both sides should meet on the centre line, at an angle of 60°. From the drawing it will be seen that the material between the two arcs struck from H is all that is really efficient in forming the arch, and that all between the arc and its chord is of no service. This breadth may be increased by making the angle at the centre less than 60°—that is, taking the centre lower down on the perpendicular line; the skew-back will not then slant so much, and the width at the crown will be more, the arch being flatter; but that portion will be less secure than by the former system, for, as the radii diverge less, they are more nearly parallel, and hence are not so tightly wedged together. These arches require to be executed with the utmost nicety, being generally of only half a brick thick, and not being bonded to the work behind them. Bricklayers usually cut the joints of gauged arches slack at the back, so as to get a fine joint on the face; the consequence is that the pressure of the load causes the arrises of the face to chip, and thus the bricks fall out; this should therefore be guarded against.

DRAWING FOR BRICKLAYERS.

In accordance with the plan laid down—viz., that the cuts in these lessons should serve not only as illustrations of the text, but as studies for drawing—we now proceed to give the student some instructions as to the method of drawing the subjects used as architectural illustrations.

One illustration previously given may, however, require a few hints to guard the student against error, viz., Fig. 62.

The subject of this is a "plain arch," that is, one in which the bricks are not cut or altered in form, but are still made to *radiate*; that is, the intrados of the arch is to be made smaller than the extrados, for otherwise an arch could not be formed; and here it is to be remembered that the difference between the small intrados and the larger extrados is made up by mortar or rough pieces of bricks, but that the bricks themselves retain their original size.

Now to draw such an arch:—

The radius of the intrados being given—viz., A B—from A with radius A B, describe the semicircle, half of which is here shown, and also the semicircle C; the width between these two semicircles being equal to the width of a brick laid on its broad side, viz., 4½ inches by scale.

Divide the intrados into as many equal parts as there are to be bricks in the inner ring of the arch; viz., 1, 2, 3, 4, etc.

It will be evident that the *centres* of these bricks radiate from the centre of the circle, though their sides do not.

Therefore, bisect each of the spaces 1, 2, 3, 4, etc., and draw radii through these bisecting points.

Now, if a line were drawn along the end of a brick it would be at once seen that the edge of the top and bottom surface would be *parallel* with this line, and of course with each other; therefore, from points 1, 2, 3, 4, etc., draw lines *between* the semicircles, *parallel* to the radii. This may easily be done with a pair of set-squares, by the method shown in the lessons in "Technical Drawing;" and thus a semicircle of oblongs will be obtained—that is, approximately so; for were this drawing executed on a larger scale, it would be seen that the inner and outer edges of the ring are made up of pieces of straight lines equal to the width of the shorter edge of the end of each brick.

For the second ring, mark off the width C D, equal to B C; set off on the semicircle C the width of the narrow sides of the bricks, as at 1, 2, 3, 4, etc.: bisect these spaces, and draw lines parallel to the bisecting lines as before.

CIVIL ENGINEERING.—III.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

WATER-WORKS.

The term *water-works* is properly applied only to such works as have for their object the collection, supply, and conveyance of water to towns for drinking and sanitary purposes, but it is also applicable in a somewhat subordinate degree to the storage and utilisation of water for agricultural purposes.

We have adverted to that great work of Egyptian engineering, Lake Mœris, which was intended as a reservoir to receive the waters of the Nile at the period of overflow, to be employed afterwards for the irrigation of the surrounding district. In all countries where the rainfall is confined to certain seasons, and is then excessive, it is imperative to provide against the effects of the dry season. In Hindostan, where the greatest periods of drought occur at certain cycles of years, the construction of reservoirs has been carried to an extreme that is not found in any other country. Advantage has been taken of every nook and ravine, and, by throwing across them banks of earth called *bunds*, they have been converted into storage reservoirs. In the Madras Presidency alone, there exist at the present time upwards of 43,000 irrigation reservoirs available for use, whilst thousands besides have become useless through neglect. The length of these bunds varies from half a mile to thirty miles. The Poniary tank, now disused, was formed by the construction of a *bund* thirty miles across the opening of a valley, and embraced an area of nearly eighty square miles. The Veranum reservoir is still in operation, and possesses an area of thirty-five square miles, the bund which effects the storage being twelve miles long. In the island of Ceylon there exist the remains of an embankment constructed for storage purposes fifteen miles long, composed of huge blocks of stone cemented together, 100 feet wide at the base, and sloping to a top width of forty feet.

These semi-natural reservoirs are to be found in Great Britain, but in smaller proportions, as, for instance, in the Pentland Hills, where one such reservoir forms the principal source of water-supply to Edinburgh.

In determining the position for a reservoir of this kind, there are several matters which require consideration irrespective of the formation of the ground. It will be necessary to determine—

1. What is the height of the proposed reservoir with respect to the town or district to be supplied from it? 2. What is the nature of the soil composing the proposed site; is it porous or otherwise? 3. What is the source of supply; is it regular, being derived from springs, or irregular, being dependent upon rainfall; and if the latter, may a sufficient amount be expected to be available in all ordinary periods of dry weather? 4. What are the difficulties to be encountered in conveying the water from the reservoir to the town?

The question of rainfall is one of the highest importance in matters of water-supply. As a rule, the rainfall is greatest in those districts which are situated towards the coast-line, whence the prevailing winds blow. For instance, in Great Britain and Ireland, the south-western districts are the most rainy; but the presence of mountains which penetrate the cool moisture-charged regions of the air causes the atmosphere to part with its moisture by condensation, and hence the rainfall occurs on the *lee* side of the mountains. The rainfall over the whole globe varies in different localities from zero to 28 feet per annum.

In addition to the foregoing considerations, if the water-supply of a town is to be *entirely* dependent upon a storage reservoir, it will be necessary to determine its loss by absorption and evaporation, and then to proportion its area accordingly. The average *annual* loss by evaporation in the temperate zone, with a mean temperature of 52·25°, is 36·5 inches. In South America, with a mean temperature of 81·86°, it exceeds 100 inches. The mean *daily* evaporation in Great Britain is less than ·1 inch.

Equal in importance to proportioning the storage area to the demand, is the consolidation of the embankment, so as to withstand the pressure of water under every possible emergency. Neither is it enough to determine what will be the water-pressure, and to proportion the breadth and slope (*batter*) of the earth-work to the strain upon it; the character of the material composing it is equally important, for above all things *percolation must be prevented.* The *least trickle* may be the commencement of wide-spread desolation. It is not necessary that the entire mass of the bank should be impervious to water, but there must run throughout it an impenetrable layer. Well-puddled clay will answer the purpose, and the most advantageous position of this layer is on the side of the bank *next* to the water, its surface being protected from detrition by a closely packed layer of stones. The main body of earth lies upon the reverse side of the puddled wall, its use being simply to act as a buttress or support to it, all that is laid upon the water-side becoming valueless as a support, since the water will penetrate it.

A regularly-constructed *weir* or escape-pipe for the overflow must be provided, so as to prevent the water escaping over loose or removable soil, and if it be an escape-pipe or culvert it should not pass *through* the bank, as there is always a tendency to trickle along the line of pipe. A syphon passing *over* the bank may be employed with advantage, and may be kept always full and ready for use by a valve at the base of the longer leg.

Having thus briefly considered the question of water-supply derived from a level *above* that of the district to be supplied, we shall now consider how best to obtain and utilise it from a [illegible] level.

There are few towns in existence which have not a river or stream of some kind either passing through or very near them, and these would naturally appear to offer the means of water-supply. But when we remember that the same streams are very generally the channels employed to convey away the sewage and refuse matter, the idea of using the water for drinking purposes vanishes. It is, however, possible under certain conditions to render such water drinkable. Nature has provided that the soil itself shall act as a filter and disinfectant to water passing through it; if, therefore, a reservoir be constructed of a soil suitable for filtration, and the impure waters be pumped into it and allowed to filter through it into another receptacle, and the same process repeated through other reservoirs, the water may be rendered fit for use. There is, of course, a limit to this process of purification, for there are streams so highly contaminated and indeed poisoned by the infiltration of chemical and animal impurities that no amount of artificial filtration will make their water pure. The black, stinking streams which flow through our northern manufacturing towns are long past all recovery as affording drinkable water. We are not, however, dependent upon streams and rivers for an efficient water-supply. The action of the soil in purifying water extends to the rainfall, which, absorbed by the ground, passes downwards by gravitation, and, being obtained from a considerable depth, is found to be highly suitable for the use of man; and here we have the great and never-ceasing water-supply, always and almost everywhere available, which Nature herself provides for us.

We are thus led to a brief consideration of wells. These are various in contruction. There is the *ordinary* dug well, and the *bored* or *Artesian* well.

Of ordinary dug wells there is the *shallow pit* into which surface water drains; such is little better than a *cesspool*, not deserving of the name of well, and yet thousands of our population are wholly dependent upon such means for their water-supply, the use of which is a fruitful source of disease and death. Some of our most fearful epidemics may distinctly be traced to the use of water derived from such a source.

The construction of *deep* wells is of very ancient date. The ancient wells of Cabul are from 300 to 350 feet deep, and many of them are only 3 feet across. A dug well at Tyre is *said* to be 3,780 feet deep. Jacob's well at Samaria is 105 feet deep and 9 feet in diameter. Joseph's well at Cairo is a wonderful piece of engineering skill. It consists of two shafts, one above the other, but not in the same vertical line. The upper shaft is 165 feet deep, and 24 feet by 18 feet in the opening. At the bottom is a spacious chamber cut down into the rock, which serves as a reservoir for the water raised from the lower shaft, which is 130 feet deep, and 15 feet by 9 feet in the opening. This second shaft is sunk at the side of the reservoir, and is reached from the surface by a spiral gallery cut in the solid rock *outside* the upper shaft, the gallery being pierced with loopholes opening into the shaft to afford light. By this gallery pass the men and mules which raise the water from the lower shaft, and discharge it into the reservoir, whence it is raised to the surface. The mode of raising the water is the same in both the shafts, and consists of the ancient Eastern system of an endless band of twisted grass passing over a large drum suspended over the mouth of the well, and lashed to which are earthen jars having their mouths all in the same direction. The drum is caused to revolve by animal labour, and the jars which descend empty come up filled, discharging their water into a trough as they pass over the drum.

The mode of construction of ordinary wells is as follows:—If the soil is of a sandy or loose nature, the sides of the well must be protected by a lining or *steining*, the most suitable materials for which are timber, stone, brick, and iron. Timber, which should be elm, may be employed as a preliminary support, or as a steining in saline strata, the salt preventing its decay. Under other circumstances timber is objectionable, as it is subject to rot. If stone is employed, it should be silicious. Brickwork is the material most usually employed, but if the water in the surrounding soil be impure, or if under considerable pressure, it is not suitable, as the water will percolate. The use both of brick and stone is, in fact, rather to keep back the *soil* than the water. Of all materials iron is the best by far for a steining. It is capable of bearing great strains and resisting great pressure; water cannot pass through it, and it is not liable to decay.

The steining of wells, whether of brickwork or of iron, is performed in sections. If of bricks, the earth is taken out to as great a depth as is consistent with safety, and a "curb," or circular ring of jointed timber, is placed on the bottom, upon which is laid the brickwork which is carried up to the surface. The curb is suspended by iron rods to cross-beams laid over the mouth of the shaft, and is capable of being lowered bodily with the brickwork upon it when required. The earth below the curb is now removed, and the steining is gradually lowered, more brickwork being added above. This process is thus continued until, if the well is deep or the soil very loose, the friction of the earth outside prevents the steining sinking lower by its own weight; it is then said to be "earth-bound." The excavation must now be continued below the first curb, and a second section of brickwork laid upon a second curb must be commenced below the upper piece, this being suspended independently of the first, and lowered in the same manner. Another mode of proceeding is to leave a portion of earth below the first curb to support it, and after a further excavation, the diameter

of which is equal to that of the *inside* of the steining, to insert a fresh curb at a certain distance below the first, and gradually removing the earth above it, to fill in the space with superposed brickwork until the first curb is reached. When iron is employed it is usually the *cast* metal, the steining being cast either entire as a cylinder, or in sections. If the latter, the sections are cast with flanges pointing *inwards*, by means of which they are bolted together, the joints being made water-tight by iron cement. The outer surface of the cylinder is thus smooth, and it may be driven down to a considerable depth before becoming earth-bound. The great advantage of a steining through which water will not percolate is that all surface and impure water is shut out from the well, and the water obtained only from the deep-seated springs, which are usually pure.

The most useful well is the *bored* or Artesian well. Bored wells are of very ancient date. They are to be found in all parts of the world, and have existed in Egypt, China, and other Eastern countries from time immemorial. There is a well bored on this principle at the old convent of Chartreux, in the town of Lillier in France, which is said to have been executed as far back as the year 1126. The *rationale* of the Artesian well is easily explained. Certain soils—such as sand, gravel, chalk—are absorbent, and permit water to pass through them; others—such as clay, loams—are non-absorbent, and do not permit the water to pass through them. Hence the rainfall is arrested in certain directions, and finds a free passage in others. But the tendency of water is to flow in *all* directions, and it will therefore move along horizontal strata if debarred from sinking lower by a clay formation. Water under these circumstances may, and often does, find its way laterally *beneath* a bed of clay or rock, and if the clay or rock be perforated, the underlying water will spring up, rising to a height equal to the height of water pressing upon it *anywhere* outside the clay. Suppose, then, a perforation be made in the soil, passing through various strata, but coming at length to a clay or rock stratum, the probabilities are greatly in favour of water rising in the bore from below the clay, and frequently to a height quite near the surface. There are even instances of the water rising *above* the surface, and forming a perpetual fountain of the purest water.

The mode of well-boring is simple, although tedious and expensive. The boring tool, which is of steel, is attached to an iron rod, to which a rotary motion is imparted. As the depth of the bore increases, the rod is lengthened by the addition of successive pieces attached one to the other by firmly-screwed joints. The shape of the boring tool varies with the kind of stratum it has to contend with. If it be rock, the tool is shaped like a chisel, so as to cut and break the stone; if clay, the tool is shaped like an augur, which scoops it out. The broken soil has to be brought to the surface by tools specially adapted for the work. The great loss of time lies in raising and lowering the tool, which has frequently to be done, and in recovering a broken tool, every portion of which must be removed before the work can proceed. The Chinese adopt a system of "jumping" in boring for water. The rod is suspended by its upper end to a windlass placed some feet above the bore, and is frequently raised and allowed to fall, a rotary motion being applied to the rod at the same time. The plan is very effectual, but the tool suffers frequent fracture.

Bored wells are only a few inches in diameter, and have in certain strata to be protected by iron steining. The joints of the successive sections of the tube are necessarily "flush" both inside and out, the mode of uniting them being shown in Fig. 2,

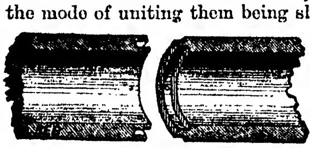


Fig. 2.

so as neither to prevent their sticking in the soil, nor yet to impede the action of the boring rod, nor the subsequent flow of water.

The supply of water obtainable from Artesian wells is frequently enormous. At Birkenhead, one such well, about 400 feet deep, yields 2,000,000 gallons of good water in twenty-four hours. Another at Kingston-on-Hull, which is sunk in chalk to a depth of 281 feet, and having a diameter of 18 inches for 210 feet of this depth, yields nearly 4,000,000 gallons in the same period. A well was commenced on Southampton Common some years since, and attained a depth—partly by digging, and partly by boring—of 1,317 feet from the surface, but water not being then obtained, it was abandoned.

In all cases of water-supply for towns it is essential to provide reservoirs to meet any sudden demand for it which may arise from fire, etc., or to provide against injury to the pumping machinery. The size of the reservoir must depend entirely upon circumstances.

The mode of disseminating the water over the district to be supplied must be briefly noticed. At the present day the water is conveyed in cast-iron pipes, the diameter and thickness of which are proportioned to the demand likely at any time to arise, care being taken to allow a fair margin for increase of population. In the early days of the New River Company, the water was conveyed in *wooden* troughs under the streets. The Company

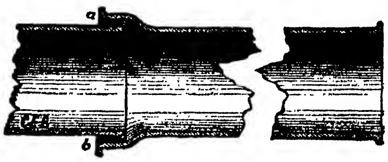


Fig. 3.

possessed at one period 400 miles of this troughing, but the leakage was so great—equal to one-fourth of the original supply—owing to faulty joints, decay of material, and bursting after frost, that they were abandoned.

The joints between the pipes have to be made with great care to prevent leakage; they are made after the pipes are bedded in their place, and the ground must be taken out at each joint to an extent to permit a man to pass entirely round it. The pipes are cast with a lip at one end, and an enlargement at the other, as shown at Fig. 3, so that the end of one fits into the enlargement of the other, as seen at *a b*. Into the recess thus formed, a flat plait of spun yarn is driven with a caulking chisel and mallet, and melted lead run into the remaining space. The principal arteries or pumping mains are the largest and strongest, and have frequently to bear a very great pressure. From these mains branch off pipes of lesser size and diminished thickness, and from these again others smaller and thinner, and so on. The valves which regulate the supply consist for the most part of a sliding plate of iron, fitting accurately in a vertical groove, and raised or lowered by a rod working in a stuffing-box. The pressure of the water being thus at right angles to the plane of movement, it exerts a comparatively small influence upon it, whilst the surface of friction is greatly less than in an ordinary tap. A throttle or balance valve could not be rendered water-tight.

When the reservoir stands upon the same or a lower level than the system of pipes through which the water has to pass, great care is necessary to render the flow in them equable. The action of the pumping-engine being intermittent, the flow of water would be reduced to a series of impulses, by which great strain would be thrown upon the machinery, without some means of keeping up the forward motion of the column of water between each stroke of the engine. There are two methods of doing this, by fixing either a vertical stand-pipe or an air-chamber over the main immediately in front of the pump. The action of the pump impels a certain quantity of water forward into the main, but the *vis inertiæ* of the mass of water opposes a certain amount of resistance to this effort, and some therefore rises into the stand-pipe—which is open at the top—or into the inverted air-chamber. In the case of the stand-pipe, the column of water takes up the force, which for a moment the engine has ceased to apply, and continues to urge forward the water in the main. In that of the air-chamber—which is simply a large and strong iron cylinder closed at the top, and communicating below with the main—the water is forced by the engine partly into the main, and partly into the air-chamber, thereby compressing the air, which, directly the pump stops, acts by its elasticity upon the water it contains, and thus continues its forward motion in the main.

PRINCIPLES OF DESIGN.—VII.

By Christopher Dresser, Ph.D., F.L.S., etc.

HARMONIES AND CONTRASTS OF COLOUR (*continued*).

Continuing our studies in colour-harmony, it must be noticed that while colours harmonise in the proportions stated, the areas may vary if there be a corresponding alteration in intensity. Thus eight of blue and eight of orange form a perfect harmony when both colours are of prismatic intensity; but we shall still have a perfect harmony if the orange is diluted to one-half its strength with white, and thus formed into a tint, provided there be sixteen parts of this orange of half strength to the eight parts of blue of full strength.

The orange might be further diluted to one-third of its full power, but then twenty-four parts would be necessary to a perfect harmony with eight parts of prismatic blue; or to one-fourth of its strength, when thirty-two parts would be necessary to the harmony.

It is not desirable that I occupy space with diagrams of these quantities, but the industrious student will prepare them for himself, and will strive to realise a true half-tint, quarter-tint, etc., which is not a very easy thing to do. By practice, however, it will readily be accomplished, and anything achieved is a new power gained.

What I have said respecting the harmony of blue with tints of orange will apply in all similar cases. Thus red will harmonise with tints of green, provided the area of the tint be increased as the intensity is decreased; and so will yellow harmonise with tints of purple under similar conditions.

But we may reverse the conditions, and lower the primary to a tint, retaining the secondary in its intensity. Thus blue, if reduced to a half-tint, will harmonise with orange of prismatic intensity in the proportion of sixteen of blue to eight of orange; or, if reduced to a quarter-tint, in the proportion of thirty-two of blue to eight of orange. Red, if reduced to a half-tint, will harmonise in the proportion of ten red to eleven of green: and yellow as a half-tint in the proportion of six yellow to thirteen of purple.

The same remarks might be made respecting the harmony of shades of colour with those of prismatic intensity. Thus, if orange is diluted to a shade of half intensity with black, it will harmonise with pure blue in the proportion of sixteen of orange to eight of blue, and so on, just as in the case of tints; and this principle applies to the harmony of all hues of colour also.

To go one step further: we scarcely ever deal with pure colours or their shades or tints, or even come as near them as we can. With great intensity of colour we seem to require an ethereal character, such as we have in those of light; but our pigments are coarse and earthy—they are too real-looking, and are not ethereal—they may be said to be corporeal rather than spiritual in character. For this reason we have to avoid the use of our purest pigments in such quantities as render their poverty of nature manifest, and to use for large surfaces such tints as, through their subtlety of composition, interest and please. A tint the composition of which is not apparent is always preferable to one of a more obvious formation. Thus we are led to use tints which are subtly formed, and such as please by their newness and bewilder by the intricacy of formation.

To do what I here mean it is not necessary that many pigments be mixed together in order to their formation. The effect of which I speak can frequently be got by two well-chosen pigments. Thus a fine series of low-toned shades can be produced by mixing together middle-chrome and brown-lake in various proportions, and in all of the shades thus formed the three primary colours will be represented, but in some yellow will predominate, and in others red; while in many it will not be easy to discover to what proportionate extent the three primary colours are present.

Let us suppose that we make a tint by adding white to cobalt blue. This blue contains a small amount of yellow, and is a slightly green-blue. But to this tint we add a small amount of raw umber with the view of imparting a greyness* or atmospheric character. Raw umber is a neutral colour, leaning slightly to yellow—that is, it consists of red, blue, and yellow, with a slight excess of the latter. In order that an orange harmonise with this grey-blue of a slightly yellow tone, the orange must be slightly inclined to red, so as to neutralise the little green formed by the yellow in the blue. It may harmonise with the grey-blue as a pure tint if the area of the diluted and neutralised primary is sufficiently extended, or may itself be likewise reduced to a tint of the same depth, when both tints would have, in this instance, the same area.

I might go on multiplying cases of this character to almost any extent, but these I must leave the student to work out for himself, and must pass on to notice that while it is desirable to use subtle tints (often called "broken tints"), it is rarely expedient to make up the full harmony by a large area of a tertiary tone and a single positive colour. Thus, we might have a shade or a tint of citrine spreading over a large surface as a ground on which we wished to place a figure. This figure would harmonise in pure purple were it of a certain size, and yet if thus coloured it would give a somewhat common-place effect when finished, for the harmony would be too simple and obvious. It would be much better to have the nineteen parts of citrine reduced, say, to half intensity, when the area would be increased to thirty-eight, with the figure of eight parts of blue and five of red, than of thirteen parts of purple.

But it would be better still if there were the thirty-eight parts of reduced citrine, three parts of pure yellow, thirteen of purple, five of red, and eight of blue, together with white, black, or gold, or all three (these may be added without altering the conditions, as all act as neutrals), for here the harmony is of a more subtle character.

If we count up the equivalents of the colours employed in this scheme of harmony, we shall see that we have, in the citrine—

Yellow	6	(two equivalents).
Blue	8	(one equivalent).
Red	5	(one equivalent).

In the purple—

Blue	8	(one equivalent).
Red	5	(one equivalent).

Of the pure colours—

Yellow	3	(one equivalent pure).
Red	5	(one equivalent pure).
Blue	8	(one equivalent pure).

Thus we have three equivalents of each primary, which give a perfect harmony.

I must not say more respecting the laws of harmony, for the space at my disposal will not allow of my so doing, but must proceed to notice certain effects or properties of colours, which I have as yet only alluded to, or have passed altogether unnoticed.

I have said that black, white, and gold are neutral as regards colour. This is the case, although many would suppose that gold was a yellow. Gold will act as a yellow, but it is generally employed as a neutral in decorative work, and it is more of a neutral than a yellow, for both red and blue exist largely in it. The pictorial artist frames his picture with gold because it, being a neutral, does not interfere with the tints of his work. It has the further advantage of being rich and costly in appearance, and thus of giving an impression of worth where it exists.

Black, white, and gold, being neutral, may be advantageously employed to separate colours where a separation is necessary.

Yellow and purple harmonise, but yellow is a light colour and purple is dark. These colours not only harmonise, but also contrast as to depth, the one being light and the other dark. The limit of each colour, wherever these are used in juxtaposition, is therefore obvious.

It is not so with red and green, for these harmonise when of the same depth. This being the case, and red being a glowing colour, if a red object is painted on a green ground, or a green object on a red ground, the "figure" and ground will appear to "swim" together, and will produce a dazzling effect. Colour must assist form, and not confuse it. It will do this in the instance just named if the figure is outlined with black, white, or gold, and there will be no loss of harmony. But experience has shown that this effect can also be averted by outlining the figure with a lighter tint of its own colour. Thus, if the figure is red and the ground green, an outline of lighter red (pink) may be employed. (See Proposition 26.)

* Cobalt, raw umber, and white make a magnificent grey, both in oil-colours in tempera (powder-colours mixed with gum-water) and in distemper (powder-colours mixed with size).

A blue figure on a red ground (as ultramarine on carmine), or a red figure on a blue ground, will also produce this swimming and unsatisfactory effect, but this is again obviated by an outline of black, white, or gold.

Employing the outline thus must not be regarded as a means of merely rendering what was actually unpleasant endurable, for it does much more—it indeed affords one of the richest means of effect. A carmine ground well covered with bold green ornament having a gold outline is, if well managed, truly gorgeous; and were the figure blue on the red ground, the lavish use of gold would render the employment of yellow unnecessary, as the slight predominance of this primary in the metal would, together with the yellow formed in the eye and cast upon the gold, satisfy all requirements.

It is a curious fact that the eye will create any colour of which there is a deficiency. This it will do, but the colour so created is of little use to the composition unless white or gold are present; if, however, there be white or gold in the composition, the colour which is absent, or is insufficiently represented, will be formed in the eye and cast upon these neutrals, and the white or the gold, as the case may be, will assume the tint of the deficient or absent colour. (See Propositions 8 and 9.)

While this occurs (and sometimes it occurs to a marked degree, as can be shown by experiment), it must not be supposed that a composition in which any element is wanting is as perfect as one which reveals no want. It is far otherwise; only Nature here comes to our assistance, and is content to help herself rather than endure our shortcomings; but in the one case we give Nature the labour of completing the harmony; while in the other, all being prepared, we receive a sense of satisfaction and repose.

In Proposition 8 we show that when blue and black are juxtaposed the black becomes "rusty," or assumes an orange tint; and in Proposition 9 we give the cause of this effect. Let a blue spot be placed on a black silk necktie, and however black the silk, it will yet appear rusty. This is a fact: but we sometimes desire to employ blue on black, and wish the black to look black, and not an orange-black. How can we do this? Obviously by substituting for the black a very dark blue, as indigo.

The bright blue spot induces orange (the complement of blue) in the eye. This orange, when cast upon black, causes the latter to look "rusty;" but if we place in the black an amount of blue sufficient to neutralise the orange cast upon it, the effect will be that of a jet black.

We have now considered those qualities of colour, and those laws of contrast and harmony, which may be said to be of the grosser sort; but we have scarcely touched on those considerations which pertain to special refinement or tenderness of effect. But let me close this part of my subject by repeating a statement already made—a statement, let me say, which first led me to perceive really harmony of colour—that *those colours, and those particular hues of colour, which improve each other to the utmost, are those which perfectly harmonise.* (Consider this statement in connection with Propositions 8, 9, 10, and 14.)

We come now to consider delicacies and refinements in colour effects, which, although dependent upon the skilful exercise of the laws enunciated, are yet of a character the power to produce which only results from the consideration of the works of the masters of great art nations; but of these effects I can say little beyond that of pointing out what should be studied.

This principle I cannot pass without notice—namely, that the finest colour effects are those of a rich, mingled, bloomy character.

Imagine a luxuriant garden, the beds in which are filled with a thousand flowers, having all the colours of the rainbow, and imagine these arranged as closely together as will permit of their growth. When viewed from a distance the effect is soft and rich, and full and varied, and is all that is pleasant. This is Nature's colouring. It is our work humbly to strive at producing like beauty with her.

This leads me to notice that primary colours (and secondary colours, also, when of great intensity) should be used chiefly in small masses, together with gold, white, or black.

Visit the Indian Museum at South Kensington,* and consider the beautiful Indian shawls and scarves and table-covers; or, if unable to do so, look in the windows of our large drapers in the chief towns, and see the true Indian fabrics,* and observe the manner in which small portions of intense reds, blues, yellows, greens, and a score of tertiary tints, are combined with white and black and gold to produce a very miracle of bloom. I know of nothing in the way of colour combination so rich, so beautiful, so gorgeous, and yet so soft, as some of these Indian shawls.

It is curious that we never find a purely Indian work otherwise than in good taste as regards colour harmony. Their works, in this respect—whether carpets, or shawls, or dress materials, or lacquered boxes, or enamelled weapons—are almost perfect—perfect in harmony, perfect in richness, perfect in the softness of their general effect. How strangely these works contrast with ours, where an harmonious work in colours is scarcely ever seen.

By the co-mingling (not co-mixing) of colours in the manner just described, a rich and bloomy effect can be got, having the general tone of a tertiary colour of any desired hue. Thus, if a wall be covered with little ornamental flowerets, by colouring all alike, and letting each contain two parts of yellow and one part of blue and one of red, the distant hue will be that of citrine: the same effect will result if the flowers are coloured variously, while the same proportions of the primaries are preserved throughout. I can conceive of no decorative effects more subtle, rich, and lovely than those of which I now speak.

Imagine three rooms, all connected by open archways, and all decorated with a thousand flower-like ornaments, and these so coloured, in this mingled manner, that in one room blue predominates, in another red, and in another yellow: we should then have a beautiful tertiary bloom in each—a subtle mingling of colour, an exquisite delicacy and refinement of treatment, a fulness such as always results from a rich mingling of hues, and an amount of detail which would interest when closely inspected; besides which, we should have the harmony of the general effect of the three rooms, the one appearing as olive, another as citrine, and the other as russet.

This mode of decoration has the advantage that it not only gives richness and beauty, but it also gives purity. If pigments are mixed together they are thereby reduced in intensity, as we have already seen; but if placed side by side, when viewed from a distance the eye will mix them, but they will suffer no diminution of brilliancy.

With the view of cultivating the eye, Eastern works cannot be too carefully studied. The Indian Museum should be the home of all those who can avail themselves of the opportunity of study which it affords; and the small Indian department of the South Kensington Museum should not be neglected, small though it is.† Chinese works must also be studied, for they likewise supply most valuable examples of colour harmony; and although they do not present such a perfect colour-bloom as do the works of India, yet they are never inharmonious, and give clearness and sharpness, together with great brilliancy, in a manner not attempted by the Indians.

The best works of Chinese embroidery are rarely seen in this country; but these are unsurpassed by the productions of any other people. For richness, splendour, and purity of colour, together with a delicious coolness, I know of nothing to equal them.

The works of the Japanese are not to be overlooked, for in certain branches of art they are inimitable, and as colourists they are almost perfect. On the commonest of their lacquer trays we generally have a bit of good colouring, and their coloured pictures are sometimes marvels of harmony.

As to the styles of colouring adopted by the nations referred to, I should say that the Indians produce rich, mingled, bloomy, *warm* effects—that is, effects in which red and yellow prevail; that the Chinese achieve clearness, repose, and *coolness*—a form

* This Museum was formerly at Whitehall.

* These will only be seen in very first-class shops.

† It may not be generally known, but nearly all our large manufacturing towns have, in connection with the chamber of commerce, a collection of Indian fabrics, filling several large volumes, which were prepared, at the expense of Government, under the superintendence of Dr. Forbes Watson, and which were given to the various towns on the condition that they be accessible to all persons who are trustworthy. Although these collections do not embrace the costly-decorated fabrics, yet much can be learned from them, and the combinations of colour are always harmonious. A much larger collection is now in course of formation.

of colouring in which blue and white prevail; and that the Japanese effects are *warm*, simple, and quiet.

Besides studying the works of India, China, and Japan, study those also of Turkey, and even those of Algeria, for here the colouring is much better than with us, although not so good as in the countries first named. No aid to progress must be neglected, and no help must be despised.

The South Kensington Museum has a very interesting collection of art-works from China and Japan; but the latter are chiefly lent. It is a strange thing that the perfect works of the East are so poorly illustrated in this national collection, while costly, yea, very costly works of inferior character, illustrative of Renaissance art, swarm as thickly as flies in August. This can only be accounted for by the fact that the heads of the institution have a feeling for pictorial rather than decorative art, and the Renaissance ornament is that which has most of the pictorial elements. To me, the style appears to owe its very weakness to this fact, for decorative art should be wholly ideal. Pictorial art is of necessity more or less imitative.

With the view of refining the judgment further in respect to colour, get a good colour-top,* and study its beautiful effects. See also the "gas tubes" illuminated by electricity, as sold in the opticians' shops, and let the prism yield you daily instruction. Soap-bubbles may also be blown, and the beautiful colours seen in them carefully noted. These and any other available means of cultivating the eye should constantly be resorted to, as by such means only can we become great colourists.

As to works on colour, we have the writings of Field, to whom we are indebted for valuable discoveries; of Hay, the decorator and friend of the late David Roberts, but some of his ideas are wild and Utopian; of Chevreul, whose work will be most useful to the student; and the small catechism of colour by Mr. Redgrave, of the South Kensington Museum, which is excellent. The student will also do well to carefully study the scientific articles on "Colour" by Professor Church in this work.

TECHNICAL DRAWING.—XV.

DRAWING FOR MACHINISTS AND ENGINEERS.

The purpose of this portion of our lessons in "Technical Drawing" is to give engineers and machinists a series of lessons in those branches of drawing which are connected with their work. The system laid down is elementary, but every endeavour has been made to render the instruction thorough, as far as it goes.

It is not long ago since the study of mechanical drawing was supposed to consist in simply copying drawings of machinery, by accurate measurement and in very fine lines. This idea has now happily exploded, but the necessity for books which should show an artisan, first, *what* he ought to learn, and then *how* to acquire such knowledge, has been deeply felt.

It is as a contribution towards the accomplishment of this purpose that the present course of lessons is put forth, in the earnest hope of aiding artisans to mount a step or two higher on the ladder of improvement.

Each part of this course of Technical lessons is, as far as possible, complete in itself; but as a knowledge of practical geometry and projection should underlie all instruction in mechanical drawing, the student is advised to read the lessons on "Practical Geometry applied to Linear Drawing" and "Projection," either prior to, or simultaneously with this; he will then be able to proceed with the advanced lessons in which the special application of those studies is shown.

Free-hand drawing of a character adapted to the wants of machinists, drawing from objects, and isometrical projection form the subjects of the various sections, and several initiatory lessons in drawing from rough sketches will be introduced, these lessons being followed with a series of drawings of modern machinery and a few simple hints on the method of colouring mechanical drawings. The examples throughout will be of an eminently useful description.

These lessons have been prepared with the greatest care, and are based on the result of long and varied experience in teaching the subject. The lessons will therefore be found thoroughly practical, whilst the information given as to the history and principles of action of the different pieces of mechanism cannot fail to prove interesting to students.

We cannot close our preliminary remarks without thanking the eminent engineers and machinists who have so kindly sent us contributions of drawings and information; had the limits of our lessons permitted, we should have gladly availed ourselves of their liberality to a greater extent than it will be found we have done. Their willingness to assist in the education of workmen shows the improved spirit of employers towards employed which is one of the most glorious features of the age we live in.

MECHANICAL DRAWING GENERALLY.

The figures given in "Practical Geometry applied to Linear Drawing," and their application in "Projection," will have shown the student the importance of absolute accuracy and refinement in mechanical drawing; and as the aim of this part of our lessons is to carry the subject to a higher stage, the necessity for perfect correctness of delineation will, as the studies advance, become more and more evident.

The first lessons are therefore designed for the purpose of offering manual practice, so as to give the student, not only the power of measuring accurately, but of drawing his lines exactly where he knows they ought to be; for, strange as it may seem to some, it is not so easy to draw lines which shall pass *exactly* through required points, or which shall be absolutely parallel to each other, as might be supposed, even though the student is furnished with rule, square, and compasses. It is hoped, however, that the practice afforded by the examples given in these lessons, and the hints accompanying them, may show the learner the obstacles with which he is likely to meet, and enable him to overcome them.

We are aware that we are addressing a body of youths and men whose work is such as to cause them to be "heavy-handed," and that the hands accustomed to wield the hammer and file with such effect as to tell upon the metal which has become more practically useful than gold, will find difficulty at first in leaning so lightly on their dividers that their delicate points shall barely mark the paper, yet we have known hammermen who in their earliest lessons crushed the very points of their pencils, become with practice expert and refined draughtsmen.

We are conscious, too, that we are writing for those who have been engaged for several hours in severe toil, whose occupation has not admitted of its being exercised in the open air, or even in airy apartments, as might be the case in many other walks of industry, but whose labour has been carried on for the most part in necessarily heated workshops, under the lurid glare of the forge-fire, amid the din of steam-hammers, and the thousand other noises inseparable from mechanical works.

It might be thought that from men so situated a sacrifice is demanded when they are urged to attend evening classes, or even to pursue home study when their day's work is over. We do not think so. We cannot believe that any man's work is really done, until he has made an effort, however small, to develop those mental powers with which he has been so mercifully endowed; and he will find, too, that the effect of the information he gains will not be confined to the evenings, but that the knowledge he acquires will increase his interest in the form and action of the machines amongst which he is engaged, and his work will not only be done better, but with greater pleasure than before.

The experience of many years has shown us that men who are desirous of working as intelligent beings, attend the evening classes with the greatest regularity, often bringing their sons to share the instruction given; and that many hours are spent at home in working out the lessons which have been received. In such practice these lessons will be found especially useful, and therefore practical hints are given so that the student may not be delayed by not knowing "how to go on."

Fig. 165 represents a drawing-board with T-square and set-square. The T-square should only be used for lines in one direction; for, unless the board be one which has recently been squared, it cannot be depended upon, and the lines drawn by means of the T-square, when guided by different sides of the board, will not generally be found to be at right angles to each other.

* Not the so-called colour or chameleon top, but the more scientific toy procurable of opticians, together with the perforated discs of Mr. John Graham, M.R.C.S., of Tunbridge, Kent.

Although a few plain hints on linear drawing, and a plain description of some of the mathematical instruments mostly used, have been given in our lessons on "Technical Drawing," some few of the remarks there given are repeated here to avoid the trouble of reference, together with such additions as the subject of these lessons renders necessary.

The best T-squares are those which have the blade screwed *across* the stock, which form (see Fig. 165) admits of the set-square being moved freely along, in order to draw a line near the edge of the paper, whilst it would be obstructed by the stock if the blade were mortised into it.

It is important that the set-square should be *true* whichever way it may be worked, and this may be tested by drawing a line against its edge when placed as at A (Fig. 165), and then turning it over as at B, bring its edge up to the line drawn; then if another drawn against the edge in its present position agrees perfectly with the former one, the square is true; if not, it will require setting.

Any working man or student will, with a little care, be able to do this for himself, by placing a sheet of very fine sand-paper on a *perfectly* flat surface, and rubbing the edge of the set-square against it, keeping the square upright, and pressing a little heavier on the part which requires "easing" than on the other.

It may be well, whilst speaking of this portion of the subject, to advise you to rub off the angles of the edges of your square. We do not mean that you should actually *bevel* them, but merely rub off enough of the sharp edge to raise it almost imperceptibly above the paper, when the square is lying flat; and we recommend you to do this to *all* the edges, for a purpose of which we shall tell you presently.

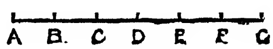


Fig. 166.

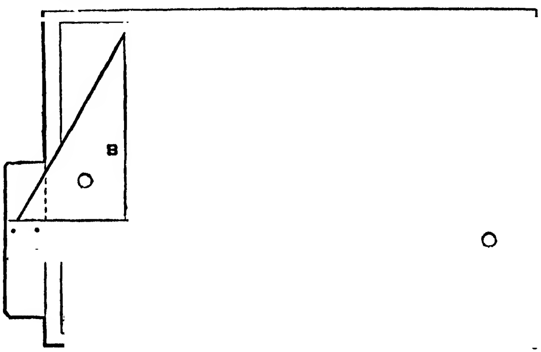


Fig. 165.

The T-square, then, being worked against the left-hand edge of the drawing-board, will give all the horizontal lines, and can be moved higher or lower without laying down the pencil or inking-pen. The lines perpendicular to the others are drawn by means of the set-square, as shown in Fig. 165. Should it be required to lengthen the line, it is only necessary to move the T-square downwards, keeping the set-square in its place against it. If these instructions are carefully followed, lines at right angles to each other will be ensured.

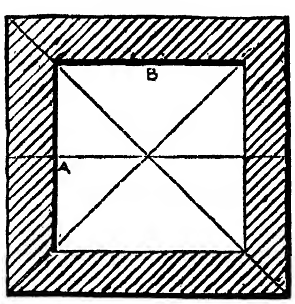


Fig. 169.

In pencilling your work you will, as a general rule, find an HB pencil the best for the larger parts, and an H for the teeth of wheels and more minute portions. Be careful not to press too heavily on your pencil; the lines should be so lightly done that they can, if required, be easily rubbed out with india-rubber, without disturbing the grain on the surface of the paper

Remember that, as a rule, mechanical drawings are not left in pencil, but that the pencil-lines are merely drawn as guides for inking. Therefore as little lead as possible should be deposited on the paper; for as the nibs of the inking-pen are drawn over the lines they gather up the grit of the lead, which lodges between them, causing the line to become thick and irregular. When, therefore, the work is finished in pencil, it is advisable to pass the india-rubber lightly over the surface, by this means removing the loose particles of lead without erasing the lines.

Draw all pencil-lines past each other at right angles and intersections; for as the edge of the rule partly obstructs your view of the line when inking, you are liable to pass over the required point, which annoyance will be prevented by another pencil-line crossing at the exact spot at which you are to stop. If you have by mistake drawn a line too long, do not scratch out the superfluous length until after you have coloured, as the roughened surface will cause the colour to run. For rubbing out an ink-line, if not too thick, you will find ink-eraser, or very fine glass-paper (No. 1), better than the knife, as it removes the surface of the paper more equally.

Never use writing-ink in your mathematical instruments. Indian ink is sold in sticks, which may be purchased at from twopence to a shilling each. This should be rubbed in a small saucer, or slab, with a little water. You should put some in your pen to try on a slip of paper, in order that you may know if it is dark enough before you begin to work with it. A little indigo rubbed with the Indian ink darkens it, and removes the brown tinge.

Drawing-boards of various kinds are sold; some are framed, some clamped, and some rabbeted. The different methods are all so many plans to secure the board against twisting and cracking; and yet all of them, however ingenious, fail, if the wood is not well seasoned before the board is made up; so that we advise you, if you are about having a drawing-board made, not to attend so much to the *make* as to the *stuff* it is made of. Most machinists who are connected with large works will have seen something of woodwork, and the carpenters with whom they may be associated will, no doubt, give them the benefit of their assistance in the matter.

To persons not so situated we suggest, that it is safer to *buy* a ready-made board, from a stock which has been some time in hand. They will then have an opportunity of selecting such as are in some degree seasoned.

For drawings such as the elementary studies in these lessons, or simple geometrical figures which are soon finished, it will be sufficient to fasten the paper down by means of drawing-pins, which may be bought at one halfpenny each; but if the drawing is likely to take some time, or is to be coloured, it is best to "stretch" the paper. This is done as follows:—Cut the sheet to a trifle smaller than your board, and turn up a margin about half an inch broad all round; then lay the paper face downwards, and spread water over the surface (the back of the sheet) with a sponge; allow the water to soak in for a minute or two, but keep the surface equally moist all over; raise the paper by its edges, turn it over, so that the wet side may rest on the board, and apply strong paste to the turned-up edges; rub these down, and in doing so draw the paper outward. It is a good plan to burnish the margin well with the handle of your penknife, by which means you press the air out, and make sure that the paper is properly pasted down. The board must then be placed horizontally to dry. If, when nearly dry, one or two large blisters remain which do not seem to decrease, prick a small hole or two in them with a needle to let out the air, which will, in most cases, remedy the evil; if not, pass the sponge over the whole face of the paper, moistening it especially towards the outer part. It is advisable to operate upon a small sheet at first, until the "knack" of stretching is acquired.

The size of the paper most generally used by students is called "imperial." This has been fixed as the size for the competitive drawings sent to the Government Department of

Science and Art, and is found the most convenient for general purposes. It is, therefore, advisable to have your drawing-board made of the same size as the paper, thus avoiding waste. The whole sheet is 30 in. × 22 in. You will find it enough for the present to use the *half* sheet, the size of which will be 22 in. × 15 in. Your board should be a trifle larger all round.

Be careful that you incline your pencil so that its *point* is guided by the set-square all along; otherwise your lines will not be upright.

When properly pencilled, dust off the lead on the surface with india-rubber, and then ink your work as already directed.

Hold your draw-pen as upright as possible, leaning your first finger on the head of the screw. If you slant the pen only one of its nibs will touch the paper, then the edge of your line will be ragged.

Before inking, rule a few lines on another piece of paper to try if your draw-pen is as open as is required to give the proper thickness of line, or if the ink is of the right colour, etc. You will find this little precaution will sometimes prevent great annoyance, and often save a drawing from being spoiled.

Fig. 167.

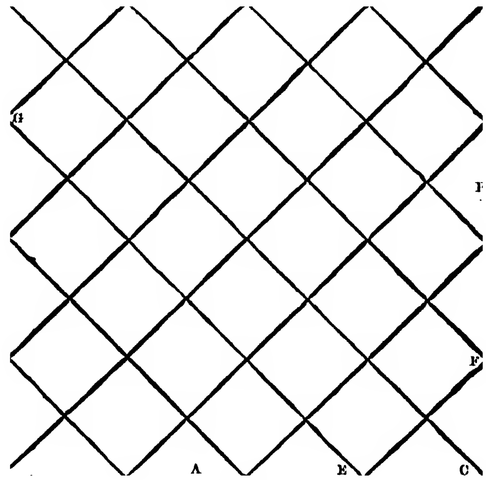


Fig. 168.

LINEAR DRAWING BY MEANS OF INSTRUMENTS.

Fig. 166.—The object in this lesson is to give practice in ruling straight lines at equal distances apart, and of the same length and thickness.

Draw a light line at the top and another at the bottom. These lines are to be ruled by the aid of the T-square, worked against the left-hand edge of the drawing-board.

Take the distance between the lines A B in your dividers, and set it off as many times along the bottom line as may be required.

(The dividers are the smaller-sized compasses without the pencil or pen legs. If you have not one of these, you must use your compass, taking care to insert the steel leg instead of that which holds a pencil.)

Having, then, set off from A the lengths B, C, D, E, F, G, keep the blade of your T-square horizontal, but moved a trifle lower down. Place your set-square against it, as shown in Fig. 165, and draw perpendiculars from the points marked.

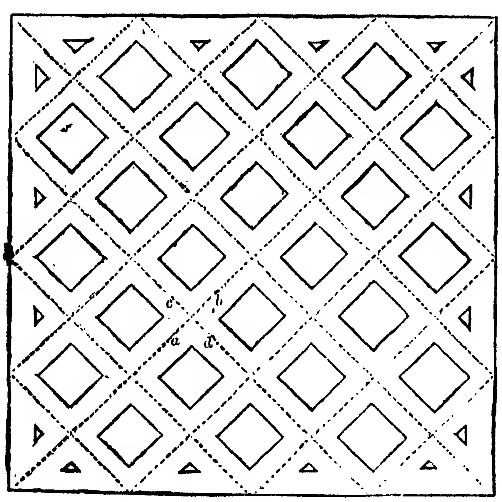


Fig. 170.

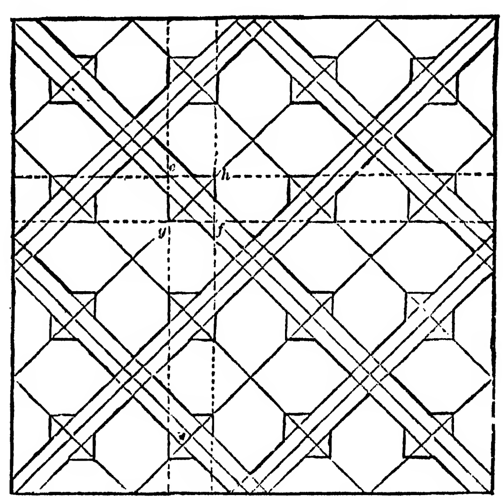


Fig. 171.

Fig. 167.—This figure will afford practice in dividing a square into several smaller ones. The study of linear drawing will have shown the geometrical method of constructing the original figure and of dividing lines; it is therefore only necessary here to advise you in drawing the square in pencil to carry the sides *beyond* the angles, which enables you when inking, and your rule covers the figure, to know the exact point at which to stop. This is important, for if you do not draw your ink-line quite long enough, you will have the trouble of "piecing" it, which is always difficult, but especially so if the line be fine;

and if too long, you will have to erase the superfluous length, which causes annoyance and trouble, and in doing which the angle of the square is often damaged.

Fig. 168 is an exercise in the accurate use of the set-square of 45°.

Having drawn the base (A), and one other side of the square (as B) at right angles to it, place the set-square of 45° so that its hypothenuse* may enter the right angle C; draw the line which will subsequently become one of the diagonals. Now from the extremities of the two sides of the square draw lines for the other two sides, and these should meet at D, *on the line* C. If this is not the case, the lines are not at right angles to each other, or there is some other inaccuracy, and you had better rub your work out, to avoid being compelled to do so when further advanced.

Having now drawn the square and one diagonal, draw the other. This must also be done with the set-square, for if your figure be accurate, the set-square placed against the one angle should give a line direct to the other. Divide the base into the required number of equal parts, and moving the set-square along the T-square, draw the lines across in each direction.

The utmost care is necessary in doing this, for it must be pointed out that it is only required to mark the division on the base, since the lines drawn from these should give the points in the sides. Thus the line drawn from E will give the point G, and if the work be correctly done the hypothenuse of the set-square when reversed should give F H and the other lines parallel to it.

Fig. 169 shows the mode of drawing lines to indicate that the drawing represents a section or cutting, and is another example of the use of the set-square, these lines being drawn at 45°. Care is necessary in keeping them all the same distance apart, and of the same thickness. The lines which on the right-hand side are thicker than those on the left are called *shade lines*. They indicate that a square *open* tube is represented, and that the light is proceeding from the left side. If it were intended to show that the walls of the tube are cut through, and that the space they enclose is filled up by a flat board not cut through, the lines A and B would be drawn of the same thickness as the other two.

Fig. 170 is an application of Fig. 168, and represents an iron grating. To draw this figure, proceed as in Fig. 168, working all the crossing lines in dots or very finely. On each side of the intersections set off half the width of the bars, as shown at *a*, *b*, *c*, *d*, and through these points, by means of the set-square, draw the necessary lines, all of which must be parallel to those previously drawn. The rest of the subject will now be easily completed without further instructions.

Fig. 171 is another application of the same study. Having drawn the original fine lines crossing the square, set off half the thickness of the bars as shown at *a*, *b*, *c*, *d* in the previous figure. From the same points mark off the semi-diagonal of the square which is to be drawn at each intersection—viz., *e*, *f*, *g*, *h*. It will be seen that one square will guide those of two lines at right angles to each other; thus *e h* and *g f* produced will give the horizontal lines of all the squares on the same line, whilst *e g* and *h f* will give the perpendiculars of all the squares above and below the square *e g f h*. If this plan be pursued, instead of measuring each square separately, much time will be saved.

ANIMAL COMMERCIAL PRODUCTS.—X.

PRODUCTS OF THE CLASS AVES

BED-FEATHERS.

THE lower barbs in feathers are usually loose, and form the down, which is called the "accessory plume." The quantity of this down varies in different species of birds, and even in the feathers taken from different portions of the body of the same bird. It is most abundant on aquatic birds, and as the value of bed-feathers depends on its amount, the feathers of ducks, swans, and geese—which have the "accessory plume" nearly as large as the feather—are the most esteemed.

The qualities sought for in bed-feathers—softness, elasticity, lightness, and warmth—are combined in common goose feathers; they are considered best when plucked from the living bird, and this cruel operation is repeated from three to five times in a year. Young birds are plucked as well as those of mature growth—the early plucking being supposed to favour the growth of the feathers. The less valuable kinds of feathers, obtained from turkeys, ducks, and fowls, are also used for bed-stuffing, and are called "poultry feathers."

Eider Duck (*Anas mollissima*).—This bird furnishes the softest, finest, and most valuable down-feathers that are in the market. Eider-down is procured from the nest of this bird, which robs its own breast of feathers in order to make a warm home for its young. The eider ducks build their nests in great numbers, in almost inaccessible rocky situations on the coasts of Ireland, Scotland, the Faroe Islands, Lapland, Nova Zembla, and Spitzbergen; and these nests are, at great risk of life, annually plundered of their down by the fowlers. Eider-down comes to this country in the form of balls, about the size of a man's fist, and weighing three or four pounds. It is so fine and soft, that if one of these balls is spread and warmed over hot coals, it will expand and fill a bed big enough for two persons. Eider-down is only used as a covering for beds, and never should be slept upon, as it thereby loses its elasticity.

In 1886 there were imported into Great Britain from foreign countries and British possessions 30,348 cwts. of bed-feathers, valued at £101,639. The importation of feathers for ornamental purposes from all parts of the world amounted, in the same year, to 689,339$\frac{6}{10}$ lbs., valued at £1,287,595.

QUILL PENS.

The earliest pens, such as were used for writing on papyrus with a fluid ink, were made of reeds. Reed pens are still in use in Arabia, as they suit the Arabic character better than quill pens. These reeds are collected near the shores of the Persian Gulf, whence they are sent to various parts of the East. Quill pens are chiefly supplied by the goose, swan, and crow—the ostrich, turkey, and other birds occasionally contributing. Crow quills are usually employed in fine drawings, on account of the fine point to which they can be brought. Goose quills are employed for ordinary writing; but swan and turkey quills, being larger, are preferable for copying.

Two principal sorts of quills are known in commerce—viz., Dutch quills, which are transparent and glass-like; and Hamburg quills, which are milk-white and clouded. Dutch quills are much esteemed; the Dutch were the first to find out the art of preparing quills for market, by removing the oil which impregnates them, and prevents the ink from flowing freely along the pen. Quills are obtained in the greatest quantities from the countries along the Baltic; Hamburg is still the principal place for preparing and exporting them. Next to the Hamburg and Dutch quills, those of Riga are much liked, especially in England.

The manufacture of steel pens does not appear to have had any very considerable effect on the demand for quills, though the latter are not so largely employed as they were once. The quills used are the five outer feathers of the wing, which are classified according to the order in which they are fixed in the wing, the second and third being the best. With proper management, a goose may afford twenty quills during the year.

In the fens of Lincolnshire, geese are kept in large numbers. During the breeding season they are lodged around the owner's house. A gooseherd, it is said, can distinguish every goose in the flock by the tones of its voice.

PRODUCTS OF THE CLASS REPTILIA.

Reptilia (Latin, *reptilia*, from *repto*, I creep).—Cold-blooded, vertebrated animals, having a heart so constructed as to transmit only a portion of the blood to the lungs. The blood is therefore imperfectly oxygenated, and there is a lower degree of animal heat. The amount of venous blood, however, transmitted to the general system varies in the different reptiles, and in proportion as there is less or more of it, is there a corresponding difference in their temperature and vital activity.

As reptiles have no need of preserving a temperature many degrees warmer than that of the medium in which they live, they are covered with scales, or hard bony plates, and without the warm clothing of the birds and mammalia.

* The longest side of a right-angled triangle.

The class Reptilia is divided into four orders, viz.:—

1. *Chelonia* (Greek, *chelone*, a tortoise), which are characterised by the enclosure of the body in a double shield or shell, out of which extend the head, tail, and four extremities. Examples: tortoise and turtle.

2. *Lacertilia*, or *Sauria* (lizards), having the body and tail elongated, the jaws furnished with teeth, the skin covered with scales, and the feet generally four in number. Examples: green lizard and blind-worm.

3. *Crocodilia* include the alligators of America, the true crocodiles of Africa, and the gavials of Asia. Gigantic lizards, covered with closely-set bony plates.

4. *Ophidia* (Greek, *ophis*, a serpent), which are distinguished by the absence of the extremities, as in the snake.

The Chelonia are commercially the most valuable of the above orders, as we derive from them two important articles—turtle soup and tortoise-shell—the former the greatest luxury of the table, and the latter the most prized of horny materials.

Green Turtle (*Chelonia mydas*).—This is one of the largest of the genus, often measuring five feet in length, and weighing between 500 and 600 pounds. It receives its name from the green colour of its fat. Its flesh is much esteemed, and in this country it is regarded as a great luxury, large quantities being continually imported for the supply of the London taverns alone. Green turtles are met with in the Atlantic Ocean, where they are widely distributed. They are found in great abundance near the Bahama Islands, and when they come ashore to deposit their eggs in holes in the sand are usually caught, either by harpooning or by turning them over on their backs, for when once turned they cannot get on their feet again. The Chinese catch them with the sucking-fish (*Remora*), which is put into the water with a string tied to its tail. The remora darts at the turtle, to which it firmly adheres by means of its sucking apparatus, and both fish and turtle are then drawn into the boat.

Mr. Darwin thus describes the capture of this turtle at Keeling's Island: "The water is so clear and shallow that at first a turtle quickly dives out of sight; yet, in a canoe or boat under sail, the pursuers, after no very long chase, come up to it. A man standing ready in the bows at this moment dashes through the water upon the turtle's back; then, clinging with both hands by the shell of the neck, he is carried away until the animal becomes exhausted and is secured. It was quite an interesting chase to see the animals thus doubling about, and the men dashing into the water trying to seize their prey."

Hawk's-Bill Turtle (*Chelonia imbricata*).—The horn-like plates of this animal, and also of the carett, or giant tortoise (*Testudo caretta*), which lives in all the seas of the torrid zone, furnish the tortoise-shell of commerce. The island of Ascension is a place of resort for these reptiles, and thousands of them are annually destroyed there. In most species of tortoise the scales which compose the carapace or upper covering adhere to each other by their edges, like inlaid work; but in the hawk's-bill turtle these scales are imbricated, or overlap one another, like the tiles on the roof of a house. The head is also smaller than in the other tortoises; but the neck is longer, and the beak narrower, sharper, and more curved, resembling a hawk's bill. The lamellæ, or plates of the shell, are semi-transparent, and variegated with whitish, yellowish, reddish, and dark-brown clouds and undulations, so as to constitute, when properly prepared and polished, an elegant article for ornamental purposes. The shell of this animal is therefore largely imported into Great Britain, several tons' weight being annually consumed by the various manufacturers. Tortoise-shell is used for the handles of penknives and razors, spectacle-frames, card-cases, ladies' side-, back-, and dressing-combs, and for inlaying work-boxes. The best tortoise-shell comes from the Indian Archipelago, where Singapore is the principal port for its exportation. It is also sent from the West Indies; from the Gallapagos Islands, situated on the west coast of South America; and from the Mauritius, Cape Verde, and Canary Islands.

"A large number of turtle eggs are secured every year for the sake of turtle oil. The eggs, when collected, are thrown into long troughs of water, and being broken and stirred with shovels, they remain exposed to the sun till the yolk, the oily part, is collected on the surface, and removed and boiled over a quick fire. This animal oil, or 'turtle grease,' is limpid, inodorous, and scarcely yellow; and it is used not merely to burn in lamps, but in dressing victuals, to which it imparts no disagreeable taste. The total gathering from the shores between the junction of the Orinoco and Apure is 5,000 jars, and it takes about 5,000 eggs to furnish one jar of oil." *

PRODUCTS OF THE CLASS AMPHIBIA.

Rana esculenta (edible frog).—This species is eaten [F]rance.

Rana pipiens (American bull-frog).—The hind limbs are considered a great luxury, and are exposed for sale in the markets of the United States.

Siredon pisciforme (the axolotl).—Inhabits the lake near the city of Mexico, where it is very abundant, attaining a length of from ten to fifteen inches. Thousands are sold, and esteemed a great delicacy by the Mexicans.

PRODUCTS OF THE CLASS PISCES.

Vertebrate animals inhabiting water, breathing by means of branchiæ or gills—vascular organs into which the circulating fluid enters, and which is submitted in a state of minute subdivision in the vessels of the gills to the air contained in the water, and so oxygenated—swimming by means of flattened expanded organs called fins, the entire body being mostly covered with cartilaginous scales. The specific gravity of fishes is nearly the same as that of the watery element in which they live. Most of them have a membranous bag at the lower side of the spinal column, known as the "air-bladder," which is so organised that the fish can vary its specific gravity by contracting or expanding the bladder, expelling the air or taking it in, and so sink or rise in the water at pleasure. It is somewhat remarkable that this air-bladder is quite rudimentary or altogether absent in fishes which live much at the bottom of the water, seldom or never coming to the surface, such as plaice, turbot, and sole. Progression in any direction is effected by the movements of the tail. The craving for food seems to be that which gives the chief impulse to their movements. Their rapacity has no bounds whatever; even when taken out of the water, and just expiring, they will greedily swallow the very bait which lured them to destruction.

The class of fishes has been sub-divided by Cuvier into two sub-classes.

1. *Pisces ossei*, or bony fishes, comprising those which have a true bony skeleton. Examples: herrings, salmon, and cod

2. *Pisces cartilaginei*, or cartilaginous fishes, including those in which the skeleton never passes beyond its primitive condition of gristle or cartilage. Examples: the sturgeon, ray, and shark.

PROJECTION.—X.

PENETRATIONS OF SOLIDS (*continued*).

PROJECTION OF BUILDINGS.

It is now necessary to develop the larger cylinder, and to draw accurately upon the development the form of the aperture through which the smaller one shall pass. Now it must be borne in mind that this aperture, notwithstanding that it is to contain a cylinder, will not be a circle when the surface through which it is pierced is laid out flat.

This will be evident on referring to the plan in Fig. 109 (page 205), where the length of the straight line *e* to *e'* is the *real* width of the penetrating cylinder; whereas the distance between *e* and *e'*, when measured on the circumference of the plan, would be much more: but as the axes of the two cylinders penetrate each other at right angles, the diameter in the elevation will remain unaltered.

The development of the general form of the cylinder will be accomplished by the method shown in Fig. 84† (page 101).

On this development (Fig. 111) draw a centre line A° representing A in the plan. The outer perpendiculars B' B'' will represent B in the plan. On each side of A° set off the lengths *g f e*, and erect perpendiculars; then the heights of the points

* See Bates' "Naturalist on the Amazon."

† The difference between this distance on the curve and on a straight line would be considerable, therefore divide it into several parts, *x*, *x*, *x*, and set them off separately, by which means the difference will be lessened.

correspondingly lettered in the elevation, marked off on these perpendiculars, will give points through which the development of the aperture may be traced.

It now only remains to develop the form of one of the ends of the penetrating or smaller cylinder. To do this, draw a horizontal line (Fig. 112), and about the middle at E erect a perpendicular. On each side of E set off the distances f, g, c, g, f, E,' into which the end of the smaller cylinder is divided, and from these points erect perpendiculars. On these set off the lengths of the lines between E E (Fig. 109) and the plan of the larger cylinder—viz., E e, F f, G g, C' B, etc. The curve uniting the extremities of these perpendiculars will give the form in which the piece of metal is to be cut, so that when rolled and joined at its outer edges, it may form a part of a cylinder of the required size which will exactly fit to the aperture in the larger cylinder already explained.

TO DRAW A CONE PENETRATED BY A CYLINDER, THEIR AXES BEING AT RIGHT ANGLES TO EACH OTHER (Fig. 113).

Draw in the first place the mere elevation of the cone, A B C, and of the cylinder, D D' E E', intersecting each other in F F' G G'; from these the general plan may be projected in the horizontal plane. The next problem for solution is the curve line may be followed throughout) the same lettering is given —namely, d' b' c'. From these points carry perpendiculars cutting the base line of the elevation of the cone in d' b' c', and draw lines from these points to the apex, C, of the cone. Intersect these lines by others drawn from b c d in the original semicircle, and through the points thus obtained the curve of penetration, starting at F and G, and ending in F' and G', is to be drawn. It is now necessary to show on the plan the curve formed at the junction or penetration of the two bodies. Four points in these curves may at once be found by dropping perpendiculars from F, F' and G, G' in the elevation to cut X X in F, F' and G, G'. Now it will be remembered that every horizontal section of a right cone is a circle, and thus the lines parallel to the base on which the points b, c, d exist, are really edge elevations of circles, the diameter of which is regulated by their position on the cone. The length from point 1' on the edge of the cone to 1 in the axis is thus the radius of the circle on which the point b, and the corresponding point beyond it, are placed. Therefore, with this radius describe a circle from the centre of the plan, and drop a perpendicular from b, cutting it in b b. Draw a circle from the same centre of the plan with radius 2 2', and a perpendicular from c, cutting it in c c. Draw a circle from the same centre with radius 3 3', and

Fig. 111.

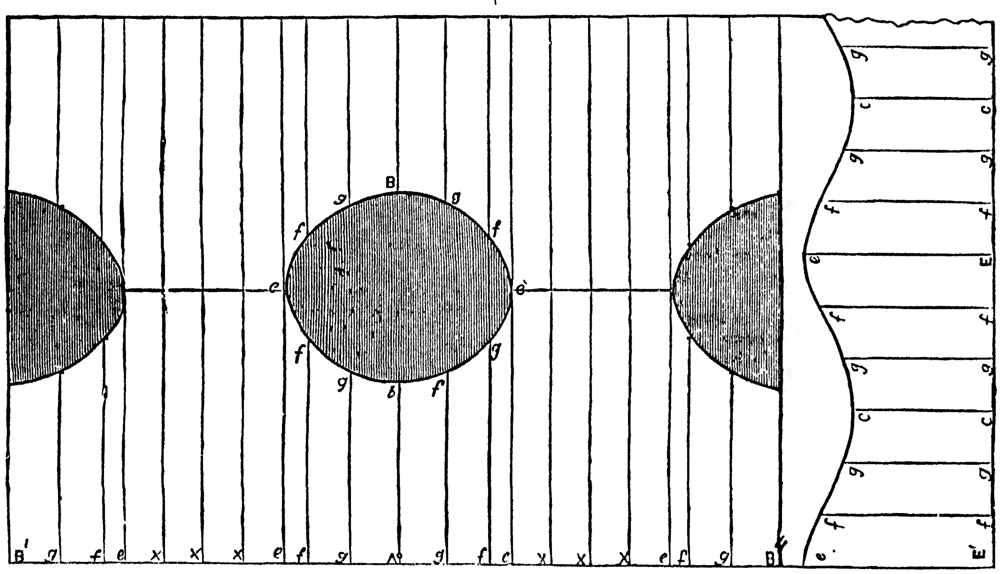


Fig. 112.

which will be generated by the intersection of the cylinder (which is a round body of *equal* diameter) with the cone (which is a round body of ever decreasing diameter). At D D' draw the perpendicular H I equal to the altitude of the cone, and from J, the middle line of the elevation of the cylinder, describe a semicircle equal to half the end of the cylinder. From I draw a line touching this semicircle in c, and reaching the intersecting line in c'. Between D and c and c and D' mark off any number of divisions, as b, d, etc. It must, of course, be understood that the greater the number of divisions marked off, the greater will be the number of points subsequently obtained, and, of course, the greater the accuracy of the intersecting curve and development; but the object of the author is to make the operations as clear as possible, and therefore, in order to avoid one set of lines passing over another, and causing difficulties and confusion, he has only marked one division (b) in the upper and one (d) in the lower portion of the elevation. The student, who is expected to work this figure to a much larger scale, will, however, do wisely to use many more points, all of which are worked in the same manner. From I draw a line through b cutting the intersecting line in b', and from I draw a line through d cutting the intersecting line in d'. Through the centre of the plan draw the line X X, and carry perpendiculars to it from c' b' d'; and from D', with radius D' d, D' b, D' c, draw arcs cutting I H produced in points similarly lettered.

From these points draw lines parallel to X X, cutting the plan of the cone in points to which (in order that the same a perpendicular from d, cutting it in d d. Draw the curve F d c b F' d c b, which will be the plan of the aperture required. (Of course the corresponding lines on the other side will give a similar result.)

TO PROJECT A SMALL CHURCH FROM THE PLAN (Fig. 114).

The church, it will be seen, is made up entirely of simple solids—viz., square prisms of various lengths, triangular prisms, and a square pyramid; and as the student has already had some practice in these, he will find, it is believed, but little (if any) difficulty in following out the instructions, although the diagram is not lettered.

The building is to be considered in the first instance as formed of the square prisms only—that is, divested of the triangular prisms which form the roof, and also of the pyramid which forms the spire.

These solids, then, will be represented in the plan by two rectangles crossing each other at right angles, and as they are equal in width their intersection is a *square*, which is the plan of the tower; the shorter end of the longer rectangle then becomes the plan of the chancel, and the longer end the plan of the nave; the smaller rectangles form the plans of the transepts. It is advisable now to proceed with the projection of the body of the church from the plan. This operation is very simple, requiring only that perpendiculars should be drawn from the various points. From the two front angles of the transept which faces the spectator, therefore, draw perpen-

diculars, and a horizontal line cutting them off at a height above the intersecting line equal to the required height of the walls of the church. This horizontal line may be drawn of indefinite length, as it will regulate the height of the whole body of the building. A perpendicular drawn from the third angle of the transept (*i.e.*, the front left-hand corner of the square) will give the one edge of the tower of which the square is the plan, and a perpendicular drawn from the right-hand corner of the square will give, not only the side of the transept, but will, if continued, give the right-hand line of the front of the tower: further, a perpendicular raised from the distant right-hand corner of the square will give the side, the height in the dotted triangle annexed. Join this point to the upper corners of the front of the transept, and this will complete its gable. From the apex of this triangle draw a horizontal line, and intersect it by a perpendicular drawn from the point where the ridge-line in the plan cuts the front line of the square. This intersection will give the point where the ridge meets the front of the tower. From this point draw a line parallel to that side of the triangle, and this will complete the visible transept; the opposite one is, of course, hidden by the body of the church, and could not therefore be seen in the present view. The student is, however, advised to project this object on the inclined plane, as shown in Lesson IV. (page 72), when the upper portion

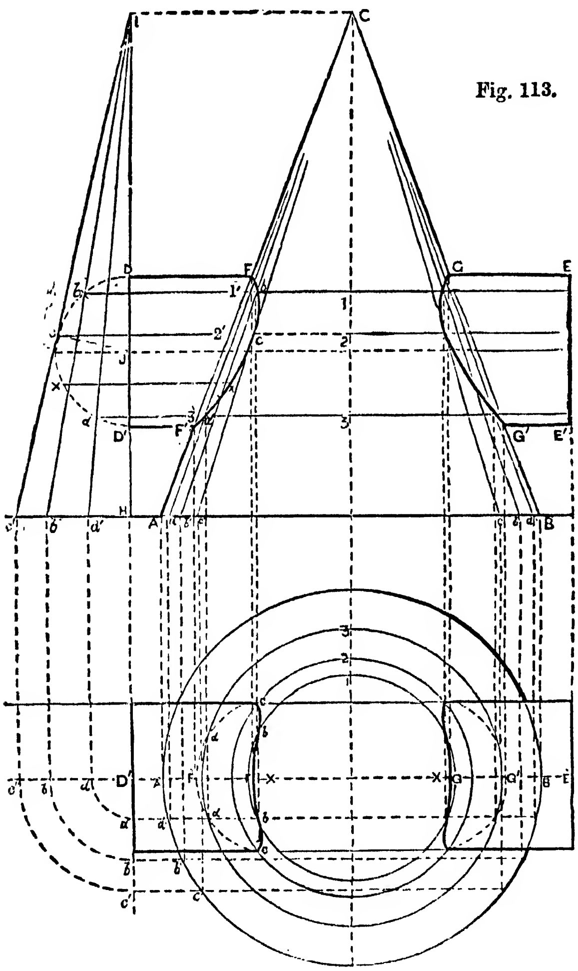


Fig. 113.

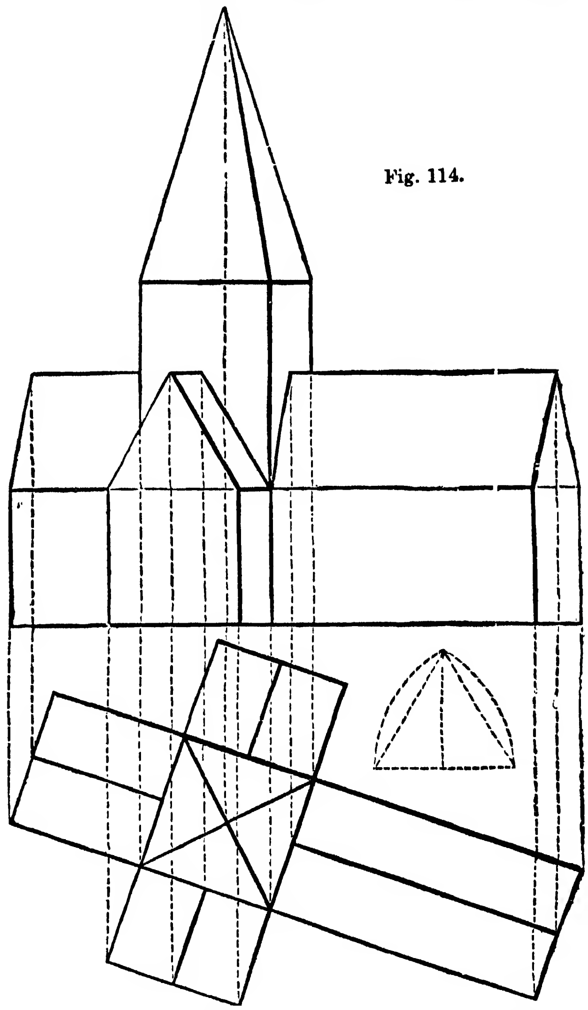


Fig. 114.

of which may be determined by a horizontal to form the top line of the walls of the tower.

Next draw perpendiculars from the two angles of the right-hand end of the longer rectangle, and these carried up will give the projection of the rectangle, or wall forming the extreme end of the nave.

We now return to the plan, and draw the diagonals, which constitute the plan of the edges of the pyramidical spire. From their intersection draw a perpendicular, and on this mark the height of the required pyramid, this line being the axis. From the apex thus fixed draw lines to the upper angles of the projection of the tower, which will complete the spire.

Again reverting to the plan, draw lines through the middle of the rectangles, which will give the plans of the ridges of the roof (Fig. 48, page 73). From the point where the ridge-line meets the front of the transept draw a perpendicular, and mark on this, above the top line of the walls, the *perpendicular* height shown at least of the hidden transept will be seen. The rectangular part of the wall at the end of the nave has already been projected from the plan, and it now only remains to complete it by the addition of the gable.

It must be obvious that the gable-point will be immediately over the point where the ridge-line meets the end of the nave in the plan; and therefore from this point erect a perpendicular, and carry it up between the two lines which represent the edges of the end of the nave. Draw a perpendicular, too, from the point where the ridge-line cuts the plan of the tower. A horizontal drawn from the gable-point of the transept will cut these perpendiculars, and give the corresponding point in the end of the nave, and in the part of the roof which meets the side of the tower. Produce this horizontal until it meets a perpendicular drawn from the end of the ridge of the chancel in the plan, and this will give the distant point in the ridge, and thus complete the projection of the church.

AGRICULTURAL CHEMISTRY.—V.

BY SIR CHARLES A. CAMERON, M.D., PH.D.,
Professor of Hygiene in the Royal College of Surgeons, Ireland, etc.

CHAPTER V.—INFLUENCE OF CULTIVATION AND DRAINAGE UPON SOILS.

WHEN crops are grown in a rich field year after year without any manure being applied to it, its soil soon ceases to be very productive. It was formerly the general opinion amongst agriculturists, and even amongst agricultural chemists, that unmanured land, if heavily cropped, would soon become perfectly infertile, or barren; but the accurately conducted investigations of Sir J. B. Lawes, of Rothamstead, and the prolonged experiment of the late Mr. Smith, of Lois Weedon, prove that it is not in man's power to reduce fertile soils to a condition of absolute sterility. Indeed, it would appear that no system of husbandry, however improvident, is capable of permanently deteriorating the productive powers of the earth.

Sir J. B. Lawes and the Rev. Mr. Smith have grown crops year after year for a long period in the same field, without the use of any kind of manure. Nor were the crops obtained very inferior either with regard to quantity or quality. Under ordinary circumstances, however, it is found expedient to restore to the soil, wholly or partly, in the form of manure, the mineral substances removed from it by crops. Tillage, or cultivation, is to a great extent a substitute for manure; and the less fertilising matter applied to the soil, the greater is the necessity for its thorough mechanical treatment. The quantity of fertilising matter present in most soils is practically inexhaustible; but only a minute proportion of it exists in a condition in which it can immediately contribute to the nourishment of plants.

We have already shown that calcic phosphate is essential to plants, and that it is an abundant ingredient of their ashes. Now every soil capable of growing vegetables contains this substance, but chiefly as an ingredient of stones and coarse particles, upon which plants cannot feed. Any one who examines a specimen of clay will see how very little of it is in the state of even coarse powder. It is the very finest powder contained in the soil which supplies the great bulk of the mineral food of plants; hence any process by which the coarse lumps and particles are pulverised increases the productiveness of the land. It was only by means of thorough cultivation that Sir J. B. Lawes and the Rev. Mr. Smith succeeded in growing crop after crop of wheat in succession, in the same field, and without the use of manure.

It would appear that the most exhaustive system of cropping may soon put land out of *condition*, but cannot affect its fertility. In practice, poor and inferior lands always remain so, whilst a rich soil can only for a brief time be reduced to an inferior condition. If, as Sir J. B. Lawes observes, it were possible by any system of cropping to abstract all, or even the greater portion, of the elements of fertility from the ground, there would not now be a fertile field in Great Britain. Needy landlords and poor tenants would long since have taken everything worth abstracting from the fields of these islands.

A good piece of land, well manured and sufficiently tilled, produces so many bushels of corn per acre. If the manure be discontinued, and the amount of tillage not augmented, an immediate and large decrease in the productiveness of the land results, and in two or three years it goes out of condition. The yield does not, however, continue to decrease, for after a short time it remains stationary for an indefinite period.

The amounts of potash, phosphoric acid, and other of the mineral elements of the food of plants are so very large in loams and clays, that it would require centuries of cropping to wholly exhaust them. They are, however, bound up in the rocky portion of the soil, and only a minute proportion of them is annually set free. It is a wise arrangement of Providence that phosphoric acid and potash should be locked up in the soil, and even that the earth should contain such small proportions of these substances. Were it otherwise—were potash, phosphoric acid, and the other ash ingredients of plants supplied in an available form, and in unlimited quantities—the husbandman could not earn his bread by the sweat of his brow, in obedience to the wise fiat of the Great First Cause. It is not a mere accident that the minerals which are least abundant in the soil are the most abundant in plants.

In very light soils, particularly those derived from the disintegration of limestones, the system of tillage without manure could not be carried on for more than a few years, without reducing the yield to an extent that would be altogether unremunerative. On the rich loams and stiff clays, which usually are very rich in potash and phosphoric acid, thorough cultivation will, without the aid of manure, produce average crops for perhaps more than a century. The maximum of productiveness is, however, attained when the land is both well tilled and abundantly manured.

The following figures show the large quantity of phosphoric acid contained in the soil, and the small proportion of it which is annually removed by crops. The soil of a field weighs at least 100 tons per inch in depth. A good soil contains 0·25 per cent. of phosphoric acid, or 5 cwt. per inch in depth. A crop of wheat removes from 12 to 15 lb. of phosphoric acid from each acre. If we assume the latter quantity, then an inch of soil would furnish sufficient phosphoric acid for 37 crops of wheat, and ten inches of soil would supply this compound to 370 crops of wheat. Other crops, no doubt, take much more phosphoric acid from the land; but, on the other hand, the fertilising resources of the super-soil admit of being largely replenished from the stores of phosphoric acid and potash buried in the sub-soil.

The chief objects accomplished by the operations of ploughing, subsoiling, grubbing, harrowing, and digging, are the exposure of the inner portions of the soil to the agencies of light and air. Under these stimulants the inert organic matter is converted into soluble plant-food, and the potash, phosphoric acid, and other fertilisers are abstracted from their stony cases, and prepared for the use of the crop. This mechanical treatment is also most beneficial in deepening the soil, whereby the roots of the plants grown in it can penetrate to greater depths in search of their food. Good cultivation also gets the land into *fine tilth*—that is, it reduces its particles to a tolerably uniform condition—increases its porosity, which augments its capacity of absorbing ammonia and carbonic dioxide from the air—and actually reduces a small portion of the soil to the finely pulverulent condition in which it proves most useful to vegetation.

The sub-soil is poorer in organic matter than the super-soil, and it contains in general less *potential* or *active* phosphates, potash, and other mineral foods of plants. For these reasons it is not desirable to bring up to the surface too much of the sub-soil; but it is useful to commingle annually a small quantity of the sub-soil with the surface one, so as to compensate for the loss of the fertilising matters which are continuously removed from the latter. A winter's action upon the crude sub-soil brought close to the air will render some of its dormant fertilising constituents immediately available for the use of plants.

It is most desirable that the mechanical treatment of the soil should not be deferred until spring. Autumn cultivation is now becoming the rule, and not, as was the case formerly, the exception. Land intended for green fallow crops should be ploughed very early in the winter, so as to render it more accessible to atmospheric influences. In the spring, grubbing is preferable to cross-ploughing, as it more thoroughly pulverises the soil. It is surprising how greatly the yield of turnips and mangolds is affected by cultivation. If the land be not thoroughly prepared for these crops, no amount of manure ordinarily applied will produce a large crop. As for the cereals, we have already shown that good crops may be produced without any manure, providing the tillage of the soil is thoroughly performed. Indeed, the term *manure* is derived from the Latin words *manus*, the hand, and *opera*, work, or hand-labour; and therefore, even according to etymology, manure and cultivation are equivalents.

Thorough drainage is one of the most important means of increasing the productiveness of soils. Excessive moisture acts injuriously by keeping the land cold; the sun's heat, instead of being usefully expended in warming the soil, is wasted in evaporating the superfluous water contained in it. 3,700 tons of water often fall upon an acre. To convert this liquid into steam or vapour, the heat derived from the combustion of 550 tons of coal would be required. In the case of stiff, undrained clays, the large quantity of superfluous water which annually descends upon them is chiefly got rid of by evaporation—a process effected by robbing the soil of the sun's heat, which is

so indispensably requisite for the maintenance of the vigour of the cultivated plants.

Heavy tenacious loams and clays are rendered more porous and friable by drainage; and after that operation their tillage can be performed with less difficulty and expense. Undrained soils are converted by heavy rains either (in the case of clays) into adhesive pastes, or (in the case of light lands) into puddles. On the contrary, a well-drained field will act under such circumstances like a water-filter, through which the water readily passes without effecting any important alteration in the condition of the filtering materials. Undrained stiff soils, when subjected to heavy rain, and then to strong heat, acquire a crust so hard that it is difficult to penetrate it. We have often seen seeds and potato-cuttings so firmly baked up in an undrained tenacious clay, that their vital powers were quite destroyed.

Unwelcome semi-aquatic plants often spring up in land which is badly drained, and they frequently succeed in overcoming and displacing no inconsiderable proportion of the plants under cultivation. When a marshy field is drained, the useless semi-aquatic plants spontaneously disappear.

The organic matter in wet soils decomposes very slowly, because of the exclusion of air. When by drainage the soil is rendered porous, the atmospheric oxygen penetrates to the organic matter, and converts it more expeditiously into water, carbonic dioxide, and ammonia—the substances that furnish to the vegetable the greater portion of its food. Every farmer knows that a wet field requires more manure than a drained one; in the former the manure remains much longer in an inert condition.

The water drained off from soils contains fertilising matters, more particularly compounds of nitric acid and sodium salts. The important fertilising substances, ammonia, potash, and phosphoric acid, are retained by the soil with great tenacity; and, on the whole, the water which passes off from cultivated soils carries with it but very small quantities of the food of plants. On the other hand, the soil is continuously receiving ammonia and nitric acid from the atmosphere.

TECHNICAL EDUCATION AT HOME AND ABROAD.

VI.—TECHNICAL INSTRUCTION IN ELEMENTARY SCHOOLS.

BY SIR PHILIP MAGNUS.

An objection to the method of science-teaching described in our previous article is that it restricts to an hour or so a week the free communication which is so desirable between the pupil and his teacher. The lesson under these conditions is necessarily a very set affair, and excellent as is the system of teaching adopted, the science lesson so given is too distinct from the ordinary school work. I can speak from personal observation, having been present at lessons given both in Birmingham and Liverpool, of the educational value of this instruction, and of its influence in awakening the intelligence of the children. But, although it may be the best kind of instruction that can be obtained for the money, it is not the best possible, and the absence of the science master from the school during the greater part of the week is a serious drawback to the value of his teaching. Another difficulty which this method only partially overcomes is the necessity of providing adequate apparatus and appliances for such lessons. It is true that the itinerant teacher brings with him, in a neatly furnished cart, the apparatus required to illustrate his demonstration. But he takes it away again; and the children are apt to look upon his experiments as clever tricks, which he may be able to perform, but which they could not. *To learn science properly the pupil must perform his own experiments.* He wants to be brought not only face to face, but hand to hand, with Nature's operations. It is in the practice of science that its chief value lies. To render this teaching really efficient, each school should be provided with its own apparatus, and the children should repeat the experiments they have seen, and do others for themselves. But to render this possible, each school must be expensively fitted with laboratories and with all the necessary appliances for practical instruction. The cost of such an arrangement renders it prohibitive, and hence we are led to consider whether an alternative scheme, which has been suggested and acted upon, is not after all preferable—that of drafting the children of the higher standards into separate schools, which, being fewer in number, may more easily be fitted with the necessary apparatus and appliances, and in which the children may obtain that practical training in science, and in the methods of experiment which constitute the true foundation of technical instruction.

But before proceeding to describe schools of this kind, I will refer to the efforts that have begun to be made to introduce specific technical instruction other than science teaching into some of our elementary schools. The Royal Commissioners in their First Report on Technical Instruction, published in March, 1882, without making any positive recommendation on the subject, indicated how strongly they had been impressed with the results of the workshop teaching which was being given in all the new elementary schools of Paris:—"The instruction in the use of tools during the elementary school age—besides being of service to every child, whether destined to become a mechanic or not—will tend in the former case to facilitate the learning of a trade, though it may not actually shorten the necessary period of apprenticeship. We should be glad to see," say the Commissioners, "this kind of manual instruction introduced into some of our own elementary schools." This suggestion was almost immediately acted upon by the Manchester School Board, which, after sending some of its members to Paris to personally inspect the results of the work done in the primary schools there, introduced workshop teaching into two of their own schools. At each of these schools the boys received one and a half hour's instruction a day; and as soon as they had got over the first difficulties of the work, and commenced to make little articles, they liked the teaching very much. In the two schools, forty-two boys were soon engaged in manual work. They were taught by a joiner, who attended both schools; the instruction being limited to woodwork—to sawing, planing, joinery, and turning. Two boys worked at each bench, the cost of which was £1 2s. The set of tools for each boy cost £1 2s. 5d. There was one lathe in each school, made at the well-known apprenticeship school in the Boulevard de la Villette, Paris, each costing £6. The cost of the material used was very trifling.

The object of such instruction is not to make carpenters or joiners, but to train children to use their hands, to understand the use of the simpler tools, and to acquire taste and aptitude for manual work. Such elementary instruction as they obtain in these schools cannot fail to be of service to them in whatever trade they may afterwards be engaged. It is very probable that instruction of the kind will be introduced into other schools of the same grade in Manchester, and the example of Manchester is likely before long to be followed in other towns.

So far, a beginning has been made. When in our primary schools the teaching of drawing shall be made obligatory, when instruction in object lessons and in the rudiments of science shall be improved, and when workshops shall be annexed to them in which the older children may have the opportunity of learning the use of tools, and of acquiring a taste for manual work—our elementary teaching will be as technical as it need be, and will afford as good and serviceable a training as the children of artisans—themselves destined to become artisans—can possibly obtain. At the same time, such a training will afford a good groundwork for those who by their superior skill and intelligence may be selected for more advanced teaching in schools of a higher grade.

TECHNICAL INSTRUCTION IN HIGHER ELEMENTARY SCHOOLS.

Schools in which the education of the more advanced children can be further pursued and specialised, with a view to their future work, do not exist in large numbers in this country. Such schools are known as "graded," or "higher elementary," schools. These schools are intended for the reception of those pupils from the public elementary schools who have passed the fourth or fifth standard, and who, unaided, or by the help of exhibitions, are enabled to continue their education for two or three years longer than would otherwise be possible. In these schools the subjects of instruction are taught in their more advanced stages; and although the number of pupils entering them from each ordinary elementary school is small, the classes are likely to be well attended in populous towns—sufficiently so to justify increased expenditure in the fitting of laboratories, of appliances for science teaching, and of improved workshops.

THE CENTRAL SCHOOLS, SHEFFIELD. — One of the best schools of this type is the Central School at Sheffield. It is a higher elementary school—*i.e.*, a school for the reception of children from the upper standards of the ordinary elementary schools. With reference to this school, Mr. John Moss, the Clerk of the Sheffield School Board, states :—

"The Sheffield School Board has, I venture to think, pioneered the way to a satisfactory solution of the question as to how the best preparation for a course of technical instruction can be provided. The higher department of its central school contemplates exactly the kind of work suited for this purpose. The majority of the 500 scholars in attendance have been drafted from the other public elementary schools of the town. The minimum standard for admission is the fourth, so the work of the whole school begins with the fifth standard; but only candidates who can pass well the entrance examination are admitted, and those who are over eleven years of age must take the papers for a higher standard.

"In less populous centres a somewhat lower standard for admission may perhaps be desirable, so as to admit of the numbers being large enough for convenient subdivision, as well as economical working.

"The advantages of this mode of selection will be appreciated by those who are thoroughly conversant with the working of ordinary elementary schools. So small a proportion of the scholars who are capable of advanced training remain long enough in any one school, that it is impossible to give adequate attention to them without sacrificing the interests of the larger numbers; and, besides, they can as a rule be far better taught by teachers who are more or less specialists than would be practicable in the ordinary schools, where the teachers are selected without reference to these particular qualifications."

In these views I generally concur. I think it desirable, however, that pupils capable of paying higher fees should also be admitted into such schools, and I believe that many of our so-called middle-class schools might be so re-modelled as to give an education very similar to that afforded in the Sheffield schools, to the great advantage of the pupils attending them.

In the Sheffield school all the pupils—both boys and girls—are taught French, and a few take German. This is an important provision in the scheme of instruction, as a knowledge of at least one foreign language has become an almost necessary part of the equipment of the technical student of these days.

The following is the programme of instruction for boys :—

Science Course.—Practical, plane, and solid geometry; machine construction and drawing; mathematics; mechanics; chemistry, theoretical and practical; magnetism and electricity.

Art Course.—Freehand, model, perspective and geometry; drawing from the cast, modelling in clay; wood carving.

Practical Work in the Workshop.—The production of simple but perfect geometrical forms in iron and wood—such as the cube, hexagonal prisms, &c.—the object of this instruction being to teach accuracy of work and skill in the use of tools.

The construction of models in wood suitable for use in schools as examples for model drawing; also of various kinds of wood joints, model doors, &c.

The construction of simple apparatus to illustrate by actual experiment the principles of levers, of levers in combination, pulleys, wheel and axle, the crane, strains on beams with different positions of load. The mechanics of the roof, arch, bridge. The more advanced pupils to be taught to construct apparatus for the purpose of illustrating the lessons given in machine drawing, applied mechanics, building construction, and mechanical engineering to evening students.

All the models to be made from working drawings prepared by the students.

It will be at once seen from the foregoing programme that this school is distinctly a technical school. It is furnished with a good laboratory, with drawing rooms, and with workshops for working in wood and metals. As working in metal is the staple industry of Sheffield, there can be little doubt of the advantage of the preliminary instruction in the use of tools, and in the properties of the materials employed, to those lads who, on leaving school, go at once into the cutlery or into any other metal-working trade. But even to those who may be engaged in other crafts, the technical skill a boy brings with him from such a school as this cannot fail to be of the greatest service in enabling him to use his hands with dexterity, and to understand the principles of the machinery he may be required to work. Although more especially adapted to the industries of Sheffield, the central school may be regarded as the type of school that might most usefully be established in all large towns in which skilled workmen and artisans of all classes are educated.

The great feature of the workshop instruction is that the boys are practised to work from drawings made to scale by themselves from rough sketches, and from data supplied to them. They show such a liking for this kind of instruction that they willingly come to school an hour before the ordinary school hours begin, and they are occupied in the shops two hours a day. With this comparatively small expenditure of time very useful results are obtained. The workshop instruction affords physical exercise to the boys, and takes the place of other forms of recreation. Just in the same way as the Kindergarten exercises direct the spontaneous activity of infants into useful channels, so manual instruction serves to develop the muscles of older children, whilst it gives them a taste for work which enables them in childhood to overcome some of the initial difficulties, which are best surmounted at an early period of life.

THE ALLAN GLEN INSTITUTION, GLASGOW.—Another school in which technical instruction is combined with ordinary elementary teaching is the Allan Glen Institution, of Glasgow.

"This school contains an elementary, a secondary, and a technical department. In the secondary department the instruction consists largely of mathematics, drawing, and science, and it serves as a preparation for the higher school. The technical department has a two years' course, in the first of which the studies are common to all the pupils, whilst in the second they are specialised, according as the pupil intends to devote himself to engineering or to chemistry. Those who stay long enough pass three years in the school workshops. In the first year they have two and a half hours' workshop instruction per week, in the second three hours, and in the third year five hours.

"The fees vary from £3 to £6 a year in the secondary school, while they are as much as £8 8s. per year for the complete course in the technical department. Nearly all the pupils of the technical department of this school come from the public elementary schools of Glasgow, which, throughout Scotland, are frequented by rich and poor alike to a much greater extent than is the case in South Britain. I am informed that the practical skill gained by these pupils, devoting during three years not more than half a day per week to workshop instruction, is fully equivalent to that which they would acquire in the first two years of their apprenticeship to an engineer."*

The school is provided with a laboratory for the teaching of practical chemistry, and a workshop, fitted with benches, vices, turning lathes, a furnace, a forge, and a complete set of tools for the working of wood and metal. The instruction in the workshop comprises a three years' course. In the first year the lads make simple articles in wood, and, to prevent waste, they are charged with the material they use, being allowed, afterwards, to take home the things they have made. After the first year, they are able to make models of parts of machinery, which are useful in the school, for the purpose of instruction, and which give reality to the science teaching the boys are at the same time receiving. These models are made from working drawings to scale, prepared by the boys from rough sketches, and the instruction is in so far similar in character to that given in the Central Sheffield School already described.

These two schools serve as very good types of what may be called intermediate technical schools—institutions the need of which is very much felt in Great Britain. They afford the best preliminary training for those who have to enter industrial life at an early age, and enable them to take advantage of the evening classes in most parts of the United Kingdom. Such schools also afford a useful preparatory instruction to the more gifted pupils whose education should be continued in one or other of the provincial colleges which have recently been established, with the view of their becoming sub-managers of works, or technical teachers.

* "Technical Instruction in Elementary and Intermediate Schools." By Philip Magnus. (Trounce and Co., Gough Square, Fleet Street.)

APPLIED MECHANICS.—V.

BY SIR ROBERT STAWELL BALL, LL.D.,
Astronomer-Royal for Ireland.

HYDRAULIC MACHINERY.

THE machines which may be classed under this heading contain some of the most beautiful examples of modern engineering skill. Water has been applied with the greatest success as a means of transmitting power for a great variety of objects. For this purpose its remarkable property of incompressibility is peculiarly adapted. We do not mean to say that water is absolutely incompressible; but it may practically be so considered, for the amount of compression it undergoes is exceedingly small.

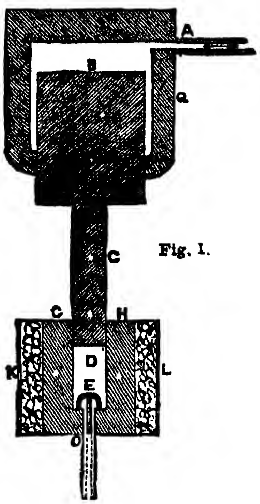


Fig. 1.

The principle and construction of the hydraulic press have been already fully explained in the pages of the POPULAR EDUCATOR (see "Hydrostatics," II., Vol. IV., page 389). To this account we therefore refer the reader for a full description of this powerful machine. We shall mention one or two important applications of the hydraulic press, and we shall then consider some other machines which are worked by water at high pressure.

The first example we shall take is the application of the hydraulic press to the manufacture of leaden tubing. The quantity of lead annually consumed in making gas-pipes and water-pipes is enormous, so the aid of machinery has been called in whenever possible. The process is one of great interest. The tubes are forced by pressure out of solid lead, which is warmed up to a certain temperature, though still far from being melted.

The apparatus by which this is done is shown in Fig. 1. P Q is the hydraulic press. This consists of a very massive iron cylinder, into which the piston, B C, fits. A is the pipe by which the water is forced into the space above the piston. The pumps which inject the water are not shown in the figure; they are worked by a steam-engine. The piston is thus pushed downwards with enormous force. The plunger is narrowed at the end, and turned so as to fit tightly into a very powerful iron cylinder, G H. It is in the space D, in the hollow of this cylinder, that the lead is placed from which the pipes are to be made. This cylinder is filled by pouring in molten lead, which is then allowed to solidify. Round this cylinder is a second cylinder, K L, containing a fire for the purpose of keeping the lead at the temperature required. This lower cylinder, containing the lead, is connected with the upper cylinder, P Q, by means of very powerful framework, so that when the pressure is exerted the piston must be forced down into D.

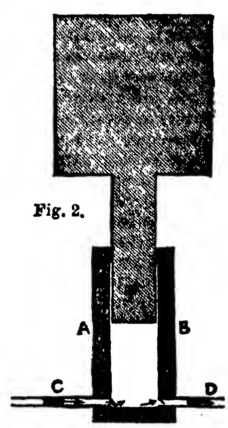
The most essential feature of the apparatus is shown at E. At O is a hole in the bottom of the cylinder, which is carefully turned, and is exactly the external size of the pipe required. A small arch is shown at E; from the top of this a mandril descends down through the hole. This mandril is exactly the internal diameter of the pipe, so that when the lead is forced between the mandril and the cylindrical hole, it is formed into the required dimensions. Under the enormous force with which the lead is compressed it becomes as yielding as putty is to an ordinary pressure. It appears very surprising at first to find that the lead is forced around the sides of the arch at E, and yet that the pipe is perfect and bears no traces whatever of the division which it must have undergone. In the earlier stages of the manufacture it was not believed that the lead would be sufficiently plastic, and consequently the mandril was fixed directly into the plunger, C, so as to avoid the difficulty of the arch. It is, however, found that equally good tubes can be made when the mandril is supported by the arch, and so this more convenient arrangement is adopted. It is very remarkable to see the lead pipe rapidly flowing from the bottom of the cylinder. It is thus made in lengths, each of which contains one charge of the vessel, G H, called the *container*. By altering the size of the hole and of the mandril different sizes of pipes can be produced.

Hydraulic pressure is especially convenient for the purpose of transmitting power. Water can be conveyed through pipes to any distance, and if force be employed in compressing the water into a pipe at one end, the water will exert force to get out at the other end. Hence we may consider that the water is just the means of transmitting the power from one end of the pipe to the other. For this purpose water is more convenient than steam, for though the steam could be conveyed through pipes, yet special means must be employed to keep the steam hot enough to prevent its condensation. Air is sometimes used for the purpose of transmitting power when from any cause the use of water is inconvenient.

As an example of this application of hydraulic power, we shall describe the machinery which is erected at Waterloo Dock, Liverpool, and at various other places throughout the country. The machinery at the place mentioned is on a very large scale, and has a great number of functions to fulfil: the dock-gates have to be closed and opened, the vessels have to be unloaded, the corn has to be raised and carried about to different parts of the immense granaries, which are capable of containing many thousands of tons. These different duties demand special machines in different parts where the work is required to be done. To accomplish this it would be very uneconomical of power, and otherwise inconvenient, to have a special engine for each machine. Most of these machines are only worked occasionally: for example, to open the dock-gates an engine of very considerable power would be required, but the gates only require to be opened now and then, and it would be very undesirable to have to maintain a fire all day for the purpose of opening the gates a few times during the twenty-four hours.

Similarly, the other machines are only worked intermittently, and out of all the machines that are employed, perhaps more than a quarter are never simultaneously in action. The case, therefore, is this: an engine, one-fourth of the power which would be necessary to turn all the machines together, will yet be sufficient for ordinary purposes, provided we have convenient means of applying its power wherever it may be wanted. Some of the machines require a great deal of power, others not so much, and therefore we also require to save up the power of the engine when working the small machines in order to have enough when a greater exertion is demanded. Water affords a most convenient means of obtaining these objects. An engine of sufficient power supplies the energy; this energy is stored up by the engine in what is called an *accumulator*, and from the accumulator it is distributed by means of water-pressure to the different machines that require it.

Fig. 2.



The accumulator is shown in Fig. 2. W is an immense weight of about ninety tons. There are guides introduced in order to restrain its motion to sliding up and down vertically, and prevent it from falling to one side. These guides are not shown in the figure. At the bottom of this weight is a plunger, P, which works tightly into a cylinder, A B. This cylinder is kept filled with water by the pipe C; the water is pumped into it by very powerful force-pumps, to work which the whole power of the engine is employed; forcing water through the pipe C into the cylinder is, in fact, the duty of the engine. Let us suppose a cock on the pipe D is turned off, then the water, when forced into the cylinder, must raise W. It is prevented from pushing P entirely out of the cylinder by a self-acting contrivance. When the weight W ascends to a certain point it acts on a lever which closes the valve supplying steam to the engine, and therefore stops the entry of water at C. Hence the engine will be constantly striving to keep the cylinder full.

The pipe D communicates with all the machines throughout

the docks which are to be worked by the pressure of the water. The water is at an enormous pressure in the cylinder. We can easily calculate its amount when we know the diameter of the cylinder and the weight of W.

Let us suppose that the diameter of the cylinder is 10″, and that the load W is 90 tons. The area of a circle is

$$\frac{22}{7} \times (\text{radius})^2.$$

From this it will be seen at once that the area of the end of the plunger is

$$22 \div 7 \times 25 = 78{\cdot}5.$$

Hence we have a pressure of 90 tons upon a surface of 78·5 square inches, and therefore the pressure on each square inch is

$$90 \div 78{\cdot}5 = 1{\cdot}15 \text{ tons}.$$

This enormous pressure is doubtless to some extent lost by friction through the ramifications of pipes by which the water is distributed; but we may probably assume that in general the pressure must be nearly a ton on the square inch. At this enormous pressure a very little water does a very great quantity of work. Let us calculate how much work is done for every pint of water that leaves the cylinder. A pint of water contains 35 cubic inches; hence, since the area of the plunger is 78·5 inches, the weight must descend

$$35 \div 78{\cdot}5 = 0{\cdot}45 \text{ inches},$$

in order to expel a pint of water along the tube D. Now, how many units of work has the cylinder exerted? This is to be found by multiplying its weight in pounds by the distance through which it descends in feet.

$$0{\cdot}45 \div 12 = 0{\cdot}0375$$

is the distance in feet, and

$$2240 \times 90 = 201600$$

is the weight in pounds, hence the number of units of work is

$$201600 \times 0{\cdot}0375 = 7560;$$

that is, it would raise 7,560 pounds through one foot, or one ton through

$$7560 \div 2240 = 3'{\cdot}4 \text{ nearly}.$$

Hence, by the consumption of one pint of water a ton weight can be raised in any part of the building through a distance of more than a yard.

The mode of working the machine will be easily understood. The weight is constantly rising or falling, rising when no large machines are drawing off the water through D, and falling when the machines are using the water faster than the engine is sending it in. Thus, when little water is used it is stored up until there is a greater demand for it.

The machines which are worked by the power of the water are of different kinds. We shall say a few words about the construction of the most important of them. The corn is taken out of the vessels by the use of machinery. An arm projects from the warehouse, which supports an apparatus by means of which little buckets upon a band descend into the hold and return filled with corn. This corn, when the buckets reach the top of the arm, is discharged into a shoot that carries it into the store, and the empty buckets descend for another load. By this contrivance a vessel is unloaded with great expedition. This machine is worked by the pressure of the water.

The corn is also hoisted from the bottom of the warehouse to the top by means of an hydraulic hoist. This is a very remarkable machine, and a description of it is the more necessary, as it has come into very extensive use.

The principle of the hydraulic hoist may be understood by Fig. 3. This diagram shows the essential principle of the machine, reduced to as simple a form as possible for the purpose of explanation. In consists essentially of an hydraulic press, and two pulley-blocks, one of which is attached to the cylinder, and the other to the plunger. The corn is raised in loads of about a ton, from the bottom of the store up to the top, through, perhaps, a height of 60 feet or more. It is, therefore, necessary to pull in the chain which is attached to the lift through a length of 60 feet.

If we have a pair of four-sheave pulley blocks, and are raising weights in the ordinary way, it is evident from the account we have already given in Lesson II., that 8 feet of chain must be pulled out for every 1 foot that the load is raised. Now, if the pulley-block be so well constructed at the axles of the sheaves that there is as little friction as possible, the weight will overhaul; that is, when lifting a weight, if we release the lifting chain the weight will descend.

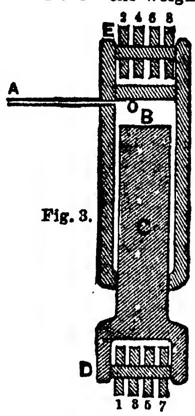


Fig. 3.

It follows, then, that for every foot the weight descends 8 feet of chain will be pulled in between the blocks. For this to occur we must have, as already explained, less than half the total force lost by friction. Supposing, now, there were a weight of 8 cwt. being raised, a force of 1 cwt. would be necessary to lift it without friction, and about 2, or a little less, with friction; but suppose the weight to descend, what strain can it produce on the lifting chain? It would produce a strain of 1 cwt. in a frictionless block, but owing to friction the actual strain is less than this. Let us suppose it to be ½ cwt., then the weight of 8 cwt. descending will raise ½ cwt. 8 feet for every foot it descends. Hence we learn that, if the blocks of a pair are forced asunder by a great pressure, the chain will be drawn in through a distance 8 times as great as the distance through which the blocks are forced apart, and a strain will be exerted upon the chain thus drawn in, which we may take as about one-sixteenth of the force pushing the blocks asunder.

Let us now apply these considerations to Fig. 3. The two blocks are shown at D and E; but the chain is not introduced, for the purpose of keeping the figure clear. The block E is firmly attached to the cylinder, and the lower block is forced away from it by admitting water at high pressure through the pipe A. The chain is attached to the upper block at O, it then passes down under the pulley 1, over 2, under 3, over 4, under 5, over 6, under 7, and over 8; to the free end hanging over 8 the lift is attached. Now, supposing the blocks be forced asunder with a pressure of about 16 tons, it is evident that the free end of the chain will be drawn in with a force of one ton, and will, therefore, be able to raise a load of 1 ton. If the stroke of the plunger be 8 feet, the lift will be raised 8 × 8 = 64 feet. As the pressure on the water is very great, the cylinder need not be very large in order to produce sufficient pressure.

There is considerable loss of power by friction in this arrangement; but its compactness and convenience quite outbalance this slight disadvantage. The hydraulic hoist has but few parts, it cannot easily go out of repair, and it can be applied wherever a pipe can be laid to carry the water to it.

After the load has been raised the water has done its work, and a valve is opened to permit its escape. The weight of the lift then pulls the chain, this raises the plunger and expels the water, and the apparatus is ready for another load.

The corn, when raised by the lift, is poured into a hopper, from which it descends to a weighing machine, which weighs it in loads of nearly a ton at a time. It is then carried by machinery to that part of the store in which it is to remain. The machinery by which this distribution is effected is very interesting.

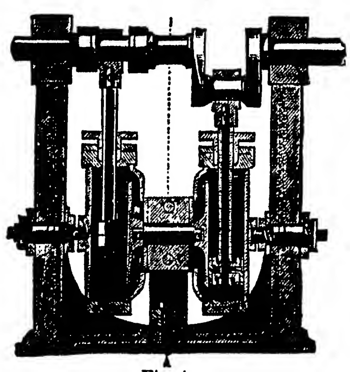


Fig. 4.

A large band, about 18″ wide, runs along the top floor of the building. This band is supported by rollers, and is worked by a small water-pressure engine.

A view of a water-pressure engine, suitable for such a purpose, is shown in Fig. 4. There are two small cylinders resembling steam cylinders, and the water is admitted to the sides of the piston alternately, just as the steam works the piston in the steam cylinder. These cylinders oscillate, and the rod of each is connected with a crank on the horizontal shaft. The cylinders need only be of small dimensions, for the

pressure of the water vastly exceeds any steam-pressure which could be used.

The machine shown in Fig. 4 has been constructed by Messrs. Ramsbottom, of Leeds. We cannot do better than give the account of its use in the makers' own words:—

"The great requisite in water machinery is to maintain a constant and equal outflow to avoid concussion, for when the momentum of water has been generated in a given direction, and its motion is suddenly intercepted by a barrier in the form of a stop-tap, or imperfect valvular action, the result is not only destructive to the machine, but represents a considerable expenditure of mechanical effect. For water-engines are nearly always double-acting, and in such cases the *valvular* action is duplicate, and we have made it a matter of the greatest importance in valvular construction to open and close the supply and exit ports slowly, and in such manner that the feed-way leading to one piston shall be in full effect when the other is absolutely closed at the termination of its stroke, and thus one set of feed and exit ways are dying gradually away to termination of stroke as the other set are opening towards full effect on return-stroke of its piston; and thus a valvular action is obtained, which not only avoids concussion but the loss of effect by avoiding the counteraction of pressure and untimely supply. We have several hundreds of water-engines employed for various kinds of work, with valvular action, as above described, and their efficiency, compactness, and convenience clearly show how much the advantages of hydraulic power are under-estimated in many of our largest towns and cities, where numerous mechanical operations might be better performed by this than any other kind of power whatever. A constant supply and adequate pressure in London would be of immense value, for unlike steam this power is neither dangerous nor offensive, but is contributive to health and cleanliness; and as in many cases the water passes directly in a pure state from the engines to the sewers, it forms a valuable flushing agent after use. Most machinery of a domestic character could be driven by water power, thus avoiding much personal attention; and the folding, pressing, and raising of goods of various kinds, as well as the working of hoists, the grinding of coffee or drugs, the driving of book-printing machines, and other uses too numerous to mention, attest the importance of soliciting increased public attention to this most natural of all the sources of motive power."

On the shaft, which is turned round by a water-power engine, a large pulley is fastened. This pulley is enveloped by the band which runs on the rollers, and when it revolves it gives the band motion.

After leaving the weighing machine the corn passes into a second hopper, from an opening in which it is poured out upon the rapidly-moving band, and is carried along by the band at a prodigious rate. About 50 tons of corn can be carried on one of these bands in an hour. By an ingenious arrangement the corn can be thrown from one band upon another at right angles, and can thus be made to turn round a corner. By means of shoots it can be delivered into any corner of the building.

There are many other applications of water-pressure hardly less interesting than those we have been considering; but our space will not admit any further discussion of them.

VEGETABLE COMMERCIAL PRODUCTS.

VIII.

FLESHY FRUITS (*continued*).

THE LEMON (*Citrus limonum*, L.).—This plant is a native of the Himalaya mountains. It appears to have been brought to Europe about the time of the Crusades. The lemon is now cultivated in all warm climates. The principal supplies to our markets are received from Italy, Spain, Portugal, Trieste, and South Tyrol. The juice and rind are both officinal. Lemon-juice is peculiarly grateful and cooling, and is much used in the preparation of effervescing draughts, and as a beverage in febrile complaints. The juice owes its sourness to the presence of a peculiar acid, called *citric*, which is easily separated by chemical means. It is one of the most powerful anti-scorbutic medicines known. That dreadful disease, the scurvy, has hardly been known in our navy since limes and lemons were ordered by law to be carried by all vessels sailing to foreign parts.

There are several other species of *Citrus* which are largely imported; as, for instance, the *Citrus limetta*, or lime, which is about one-third the size of a common lemon, and which is exported in the green state, in order to preserve the delightful aroma of its rind. The preserved lime comes to us in small kegs of about 7 lb. weight. The *Citrus bergamiæ*, or bergamot, bears a fruit closely resembling the lemon. As a preserve it is used as a substitute for citron, but its chief value lies in the oil obtained from it—the well-known bergamot so much used in perfumery.

GRAPES (*Vitis vinifera*, L.).—The fruit of this vine not only furnishes us with a variety of wines, but is itself imported into this country both in the fresh and the dried state. Though at one time comparatively few grapes came to England in a fresh state, the quantity thus imported is now large. They suffer in their flavour from being closely packed, and still more from the use of sawdust as a packing material. Raisins, or dried grapes, are far more abundantly imported. These are prepared sometimes by cutting the stalks of the bunches half through, and leaving them suspended to the vine until sufficiently dry, which in this state they rapidly become, without losing any of their fi e flavour or bloom; the usual mode is to expose the grapes to the sun and air for a while, then lay them out in rooms, and sprinkle them with water in which soda or potash has been dissolved. This causes the sugar of the grape to candy, forming those little sweet lumps so well known in the common raisin. The differences amongst the raisins are caused entirely by difference in their mode of culture or curing. Thus we receive stoneless sultana raisins from Smyrna, in Turkey; fine muscatels, or sun-dried raisins, in bunches with the stalks still attached, from Malaga; Damascus raisins, much larger than the sultanas, stoneless also, and preferred to the Smyrna raisins, from Damascus; and lastly, the ordinary raisins from Valencia, and from the same countries and ports where the grape is cultivated.

Currants are only the raisins of a small grape, also deficient in seeds or stones, growing in huge bunches, often as much as eighteen inches long, and of proportionate breadth. They are trod into large casks, and exported. Enormous quantities are cultivated in the Grecian islands, principally in Corfu, Zante, and Ithaca. Originally, Corinth was the principal place where they were raised, whence the name "Corinths," from which the word "currants" has been derived. In 1886, 841,066 cwts. of currants, valued at £1,078,622, and 493,673 cwts. of raisins, valued at £812,988, were imported into the United Kingdom.

FIG (*Ficus carica*, L.; natural order, *Urticaceæ*).—This is a very valuable and extensive genus of tropical and sub-tropical plants, some of the species attaining an enormous size, as the *Ficus indica*, or celebrated banyan tree. The fig tree, originally a native of Asia, now flourishes in Southern Europe, on all the islands in the Mediterranean, and especially in Asia Minor, Northern Africa, and the Canary Islands.

The fig, considered botanically, is a very remarkable form of fruit, being just the reverse of that of the strawberry, in which the minute pistils are scattered over the exterior of the enlarged succulent receptacle; whereas in the fig the inflorescence or position of the flowers is concealed within the body of the fruit. There is sometimes a failure in the fig crop, when it is not properly attended to, in consequence of the pistils of the florets not becoming duly fertilised by the pollen of the stamens. It is supposed that this operation is caused naturally by the entry of insects through the very small orifice which remains open in the flowering fig; the fig-growers therefore adopt an artificial means of ensuring fertilisation—a small feather is inserted and turned round in the internal cavity. This operation is called "caprification."

Figs are sent to us in large quantities from Turkey and Greece —those from Turkey being the best. The fig, after having been gathered from the trees and dried in the sun, is usually packed in square or circular boxes, the latter being called "drums." A few bay leaves are put upon the top of each box, to keep the fruit from being injured by a grub, which feeds on it and is very destructive. The Maltese figs are very good, but those which come from Smyrna, called "Eleme," or "Elemi," are the best.

The fig is nutritious, laxative, and demulcent, acting gently in cases of habitual constipation. Roasted and split, it is some-

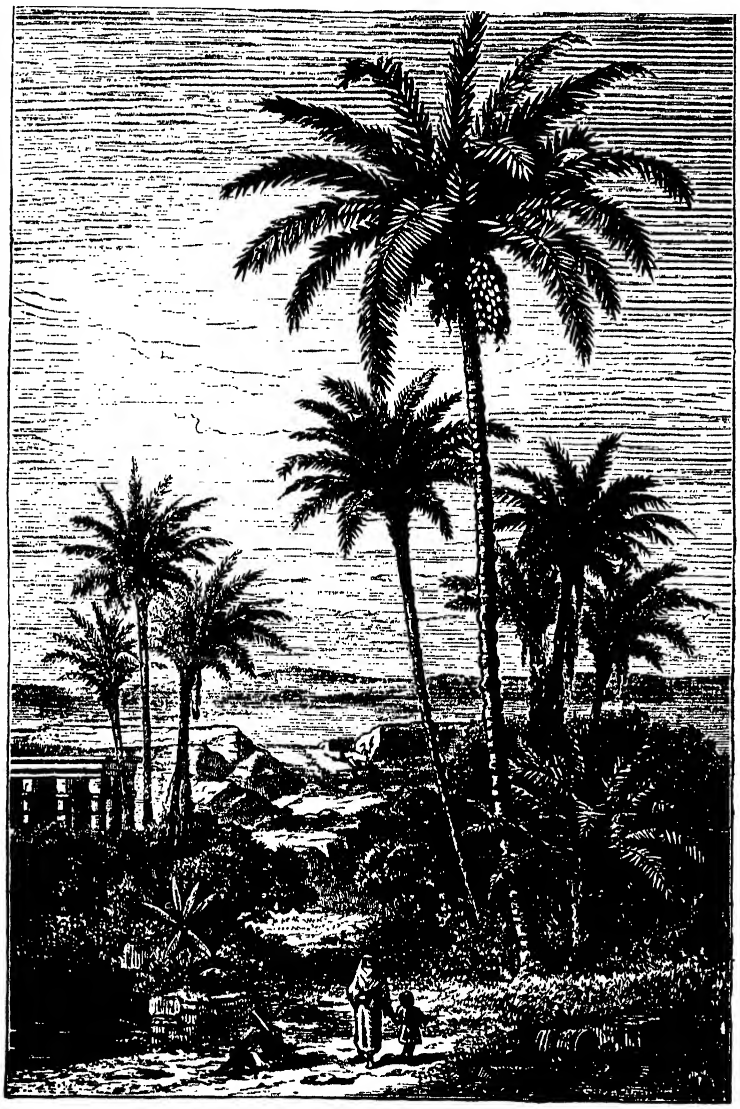
times applied to gum-boils and other circumscribed maturating tumours. It was used by Hezekiah as a remedy for boils 2,400 years ago. (See Isaiah xxxviii. 21.)

In 1886 there were imported into Great Britain 114,253 cwts. ,, valued at £211,276.

PRUNE (*Prunus domestica*, variety *juliana*; natural order, *Rosaceæ*).—Dried plums, under the names of prunes and French plums, form an important article of commerce. The prune is the common plum dried in the sun; the prunes are then thrown together and pressed into barrels. We receive them in large quantities from France. The imports in 1886 amounted to 21,124 cwts.

Prunus domestica, variety *catherinea*, is the French plum or table prune. These are more carefully prepared for market. They generally come over in very elegant boxes called cartons, into which they are neatly packed one by one. In 1886 there were imported 12,523 cwts.

THE DATE PALM (*Phœnix dactylifera*, L.).—This palm has been known and prized from the earliest antiquity; it is frequently referred to in the Bible. The fruit is very nourishing and wholesome, and grows in bunches weighing from twenty to twenty-five pounds. Every part of this tree is useful. Its hard wood is employed for building; its leaves are made by the natives into mats, baskets, and drinking bowls of great neatness; its seeds are ground to make oil; and its fermented sap forms an excellent wine.



THE DATE PALM.

In Corsica, Sardinia, and in Southern Greece the date palm is planted only as an ornamental tree, as its fruit does not mature in these parts, or ripens only imperfectly. In the very warmest districts of Spain, around Valencia, the fruit comes to perfection, and is exported. The date palm is indigenous to Arabia and Northern Africa, where it is very abundant. In those countries plantations of these trees are sold as estates, and are often the wedding portion of the bride. In some parts of Arabia this palm sometimes forms almost impenetrable forests when neglected by the Arab of the desert, who usually considers every kind of cultivation beneath his dignity. More frequently, however, it is found in a solitary state near a spring, thus presenting to the thirsty traveller a welcome signal, which assures him of water for refreshment, and of a friendly shade for repose.

The best dates come to us from Tunis *viâ* Marseilles. The quantity annually imported into England has increased very greatly of recent years.

POMEGRANATE (*Punica granatum*, L.; natural order, *Myrtaceæ*).—A small evergreen shrub, resembling a myrtle, with numerous slender spinose branches; leaves opposite, entire, lanceolate, bright green, and sessile; flowers large, terminal, and rich crimson in colour. The fruit is about the size of a large poppy head, and similarly shaped; its rind hard, leathery, and beautifully coloured; yellow, with a rosy tinge. When the rind is broken, the interior of the fruit is found to be filled with numerous seeds, each enveloped in a rose-coloured pulp, packed together in two rows, with partitions of pith between them, and closely resembling red currants.

There is scarcely a part of the pomegranate that is not either useful or agreeable. The pulp of the fruit is refreshing to persons suffering from fever. The seeds and flowers dried form a valuable medicine, and are used in dyeing, and the rind is employed in tanning and preparing the finer kinds of leather, as the morocco, so much used for bookbinding.

The pomegranate is a native of Northern Africa, Syria, and Persia, but it is now naturalised in the warmer parts of Europe, the West Indies, and the Southern States of the American Union. It was known to the ancients, is mentioned by Homer, and also frequently referred to in the Bible. We receive annually a considerable number of chests of pomegranates from Portugal, and sometimes from Barbary. This tree is frequently cultivated as much for the beauty of its flowers and foliage as for its fruit.

TAMARIND (*Tamarindus indica*, L.; natural order, *Leguminosæ*).—This is a large tree, with spreading branches, and abruptly pinnate leaves, the leaflets closing in the evening or in cold, moist weather, like those of the sensitive plant. The flowers are in simple racemes, the petals yellowish, variegated with red veins; these are succeeded by an oblong, compressed, one-celled, brittle, brown pod, from three to four inches in length, which encloses from six to twelve brown, flattened, hard, polished seeds, enveloped in a soft pulp, the whole being held together by a number of thick root-like fibres which penetrate it in all directions.

The tamarind is common in the East Indies, where it is indigenous, and grows in great perfection. It is now introduced

and extensively cultivated in the West Indies and in South America; but the fruit there is not equal to the East Indian, having much less saccharine matter in the pulp. The tamarinds from the East Indies are darker, have a larger and sweeter pulp, and can be preserved without sugar; those from the West Indies require sugar, and are sent over preserved in a thick saccharine syrup.

The tamarind pods are gathered when ripe, a fact known by their brittleness; the fruit is removed from the pod, placed in layers in a cask; boiling syrup is poured in; and when the cask is filled, and its contents have cooled, it is headed down for exportation.

In tropical countries the tamarind is much esteemed for its cooling qualities; its taste is acid and agreeable, and it assuages thirst. Tamarinds are principally employed in this country to form cooling medicinal drinks. Large quantities arrive annually from the East and West Indies.

BANANA (*Musa sapientum*, Tournef.; natural order, *Musaceæ*).—This may be called a stemless plant, for its gigantic leaves, with their long petioles, are sheathing and imbricated at their base, and form, by their union, a spurious trunk, often many feet in height. The leaves are from four to six feet in length, rounded at each end, and about eighteen inches in breadth throughout their whole extent; they have a strong mid-rib, parallel, lateral veins, and are of a beautiful emerald-green colour. The flowers are spathaceous, and produce large clusters of succulent indehiscent fruits, each fruit being an inch in diameter and about six inches in length. When ripe, the banana acquires a rich golden-yellow colour; the outer envelope or exterior of the fruit is easily removed; the inner portion consisting of a rich cream-coloured pulp contains a considerable quantity of sugar and starch.

The banana forms an important article of food in the tropics. Some idea of its fruitfulness may be gathered from the statement of Humboldt, that the same space of ground which will grow thirty pounds of wheat, or ninety-nine pounds of potatoes, will afford 4,000 pounds of bananas. Those intended for exportation are generally gathered green and unripe, but soon acquire, on being kept, that golden tint which marks maturity. Several other species of *Musa* produce similar fruits. *Musa paradisiaca* yields the plantain, a fruit bearing a close resemblance to the banana, and equally nutritious.

PINE-APPLE (*Ananassa sativa*, Lindl.; natural order, *Bromeliaceæ*).—This is a stemless plant with rigid, re-curved, channelled, and spinose leaves. The fruit is called in botany a *sorosis*, and consists of a union of the ovaries, floral envelopes, and the succulent axis of the inflorescence, which become pulpy and confluent with each other. The fruit is so acid in the wild state, that when eaten it removes the skin from the lips and gums; cultivated, it becomes sweet and agreeable to the palate, and richly aromatic.

Originally indigenous to the Bahama and Bermuda Islands, the pine-apple, owing to its value as a fruit, and its capability of becoming naturalised, is now cultivated, not only in the East Indies and Africa, but in all parts of the world where it can be grown either by natural or artificial means. Owing to the introduction of steam navigation, vessels can now bring ripe pine-apples from the West Indies to England in pretty good condition; and their importation has become a very extensive trade. Consequently, this fine fruit is often sold in London and other large towns at a cheap rate compared with the price asked for those grown in English hot-houses. English-grown pine-apples are worth from ten to twelve shillings per pound, whilst those imported rarely exceed half-a-crown for the entire fruit. Inferior pine-apples are frequently sold in the streets at a penny a slice.

(b.) NUTS.

HAZEL NUT (*Corylus avellana*, L.; natural order, *Cupuliferæ*.—This familiar edible nut is found growing wild in the United Kingdom, in the forests of all parts of temperate Europe, and in many places in Asia. The consumption is immense, especially amongst children; and many thousand bushels are annually brought to this country from Spain, Sicily, Smyrna, and other places. The filbert is only an improved variety of the common hazel nut, and although occasionally imported, is usually cultivated in sufficient quantities in England to supply the demand.

COLOUR.—V.

By PROFESSOR A. H. CHURCH, M.A., Royal Academy.

THE SECONDARY AND TERTIARY COLOURS—CONTRASTS OF TONE AND OF COLOUR.

Secondary colours may now engage our attention. On referring to the central figure in the coloured diagram, it will be seen that the three primaries occupy the angles of the first triangle, and the three secondaries the angles of the second. If we represent the same arrangement without colour (Fig. 13), we shall be able to point out very clearly the constituents of each compound colour. The three small triangles marked I. contain the three primary colours, while those marked II. contain the three secondary colours. When equivalent quantities of yellow and red are mixed, orange is the result—a secondary colour equally distant from yellow on the one side and red on the other. It is commonly held that, with material pigments, three parts (by surface measurement) of a good yellow require five parts of a good red to form the normal orange. The eight parts of the normal orange formed in this way will serve as a complementary equivalent to eight parts of the normal blue. But, after all,

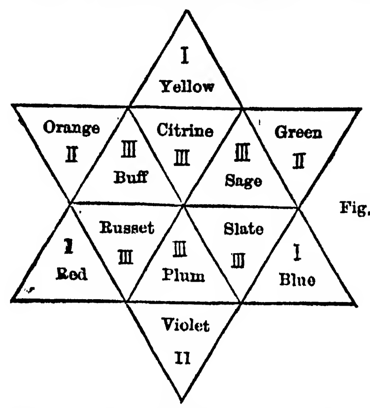


Fig. 13.

these and similar numbers are merely approximate, serving just to indicate the direction in which one coloured constituent must preponderate over another in such mixtures as the secondary colours. When yellow and red are mixed in proportions differing from those necessary to constitute the normal orange, the resulting colour becomes a yellowish-orange or a reddish-orange, according to the predominance of either of the constituent primaries: countless variations of a secondary colour in this direction are possible. Indeed, as we have already shown, most of our coloured materials, usually regarded as exhibiting primary colours, in reality furnish us with secondary hues of this kind, though their mixed character is not perceived by the unassisted vision.

The following list shows the imaginary or theoretical composition of the three secondary colours, and their six chief modifications or hues. The letters Y, R, and B represent the equivalent proportions of the three primaries—yellow, red, and blue; the equivalent of yellow being assumed to be 3, of red 5, and of blue 8:—

SECONDARY COLOURS.

Y + R = Orange.
R + B = Violet.
B + Y = Green.

SECONDARY HUES.

2Y + R = Yellowish-orange.
Y + 2R = Reddish-orange.
2R + B = Reddish-violet.
R + 2B = Bluish-violet.
2B + Y = Bluish-green.
B + 2Y = Yellowish-green.

Orange.—This colour is the most powerful and brilliant of the three normal secondaries. It is seen in the pigment known as cadmium yellow (the cadmium sulphide), and in the skin of a rich-coloured ripe orange. To make a pure and bright orange by mixture, it is essential that the yellow pigment should incline to red rather than to green, and the red pigment to orange rather than to blue. If the contrary be the case, and a greenish

yellow pigment be mixed with a red, or a yellow with a violet-red, a certain amount of grey is produced by the combination of the three primaries present, and a dulled tone of orange is the result. The worst effect of this kind is produced when a greenish-yellow is mixed with a violet-red. Gamboge and carmine form an orange far inferior in purity to that produced by the admixture of chrome yellow and vermilion.

Violet is the least powerful of the secondary colours. The aniline dye known as mauve may be taken as somewhat near the normal violet. Many other artificial colouring matters made from the products of coal-distillation also approach this beautiful colour. Violet usually appears much redder and duller by candle- or gas-light than by daylight. The yellow and orange rays which are present in peculiar abundance in most artificial lights, neutralise some of the blue in the violet, forming therewith grey, and at the same time setting free, as it were, the red element of this secondary combination. To make a pure and bright violet by mixture, it is essential that the red pigment should incline to blue rather than to orange, and that the blue pigment should incline to red rather than to green. Vermilion and cobalt produce a very dull and earthy-looking combination, owing to the presence of orange in the former colour and green in the latter. Carmine and ultramarine afford a more satisfactory mixture.

Green is more vivid than violet, but less so than orange. It occupies a considerable space in the solar spectrum, where, however, much of the green light has a yellowish hue, and some of it inclines towards blue. Emerald green is in reality far from reflecting pure green light only to the eye. Its spectrum is simply deficient in red and orange rays, yet even these are by no means absent. The new "aniline green," which retains its characteristic and brilliant colour by artificial light, absorbs, when of sufficient purity and in sufficient amount, nearly all rays except the green. When a piece of cotton dyed with this green is interposed between a light and the spectroscope, it will be found that about six thicknesses of the fabric are requisite to strain off all the red rays. But this result may be accomplished more easily by a solution of the colouring matter; for in this case there are no interstices through which light can pass, and thus escape the selective absorption of the pigment. Viridian, the beautiful and permanent chrome green introduced of late years, transmits the green rays or green portion of the spectrum unchanged, but along with them a small portion of the red and of the blue rays. In producing a green by admixture of yellow and blue, it is important to take a yellow and a blue both free from red. A greenish-yellow and a greenish-blue, or else a pure yellow and a pure blue, may be successfully used. Notwithstanding its brilliancy, cadmium yellow, which is really an orange, cannot be made to yield a satisfactory green by the addition of any kind of blue pigment.

Tertiary Colours have now to be considered. Referring back to our diagram (Fig. 13), we find six spaces marked III. Each of these spaces is immediately contiguous with a space (marked I.) assigned to a primary, or to a space (marked II.) assigned to a secondary colour. We have already alluded to the fact that the so-called tertiary colours ought, strictly speaking, to be regarded as nothing more than dulled tones of the primary and secondary colours. Indeed, it is impossible, on the theory of the three primaries together forming grey, to have any colour which shall exhibit the colour-effect of more than two of them together. An examination of the composition of the tertiary colours will explain this point. Using again our former symbols for the primaries, and letting Gy stand for grey, we may express the constituents of the six normal tertiaries thus:—

$2Y + R + B = Y + Gy$ = Yellow-grey, or *citrine*.
$2Y + 2R + B = Y + R + Gy$ = Orange-grey, or *buff*.
$Y + 2R + B = R + Gy$ = Reddish-grey, or *russet*.
$Y + 2R + 2B = R + B + Gy$ = Violet-grey, or *plum*.
$Y + R + 2B = B + Gy$ = Bluish-grey, or *slate*.
$2Y + R + 2B = Y + B + Gy$ = Greenish-grey, or *sage*.

It is commonly stated that the tertiary colours are compounded of the secondary colours. Thus the two secondaries, orange and green, are assumed to give rise to the tertiary colour known as *citrine*. This hue is really nothing more than a yellow-grey; for its orange constituent contains yellow and red, and its green constituent yellow and blue. Subtracting equivalents of the three primaries, so as to form grey, we have, therefore, nothing but a residue of the primary yellow, to produce the whole colour-effect of the mixture of the secondaries orange and green. This residual yellow is dulled by the presence of the grey which is the product of mixing equivalents of pigments representing the three primaries. The colour complementary with citrine or yellowish-grey is violet, which, of course, supplies the blue and red which have been extinguished in the former hue.

The secondary colours orange and violet produce, when mixed together, the tertiary hue known as russet. It is really a reddish-grey. Some autumnal leaves present good examples of this colour. Its complementary is green, which supplies the yellow and blue which are wanting in russet.

The secondary colours green and violet produce, when mixed together, the tertiary hue often called olive, but which may, perhaps, be more correctly designated slate. It is really a bluish-grey. The complementary colour is orange, which supplies the missing red and yellow constituents.

We may here name, as other and very useful tertiary hues, those known as buff, plum, and sage. Buff, or orange modified by grey, may be produced by the addition of red to citrine, or by mixing the three primaries so that yellow and red predominate. Sage-green is produced by the addition of yellow to slate-colour, or by mixing the three primaries so that both yellow and blue predominate. Plum-colour is a violet-grey produced by the addition of blue to russet, or by mixing the three primaries so that both blue and red predominate.

Numerous other tertiary hues, besides the six just named, are constantly observed in natural objects, and may be reproduced with great advantage in decorative art. It is, however, very difficult to describe the composition and character of such colours.

Contrasts of tone and of colour.—If there be the slightest difference either of tone or of colour in two contiguous or neighbouring coloured or shaded surfaces, that difference will not be seen exactly as it really exists. Under such conditions, either the retina of the eye receives an impression which does not actually reproduce the facts of the exterior phenomenon, or the message transmitted to the brain is itself modified. Whatever the exact cause, the study of the *subjective* modifications of tone and colour is one of the most important branches of our present series of lessons. We shall describe, first of all, contrasts of tone, and then contrasts of colour.

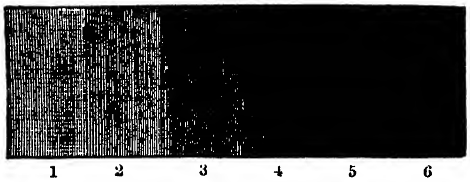
Contrasts of tone may be either successive or simultaneous. Of the first kind, we have examples in the facts that a dark-toned piece of cloth or paper looks lighter if we have immediately before been looking at a still darker piece; and that a light-toned piece looks darker, if we have immediately before been looking at a still lighter piece. The following are illustrations of the facts of the simultaneous contrasts of tones:—We first take two strips of pale-grey paper, and fix them a few inches apart towards one side of a piece of linen stretched across a window. Two similar strips are next prepared, but they are to be of a considerably darker tone. One of these is placed so as to touch one of the first strips; the other is fixed at some few inches' distance. The following sketch shows the arrangement of the strips:—

Pale.	Pale.	Dark.	Dark.
A	A′	B	B′

Upon steadily looking at the four sheets for a short time, it will be perceived that A′ close to B seems lighter than A, while B close to A′ seems darker than B′. The effect of contrast in altering the tone of the contiguous strips A′ and B may be further studied in this way. Make such openings in a piece of card as to divide the strips A and B each into three portions. It will then be noticed that the two nearest portions are most contrasted in tone, and the others less so in proportion to their distance from the line of contact. But the effect of contrast of tone is still better seen when a more complete series of toned strips is placed in contiguity. In such a case the effect on all the strips, save the end ones, is that of a double contrast. The second strip, or second tone, has one side of it made apparently darker by reason of the contiguity of the lighter tone of strip 1, while the other side seems lighter by the contiguity of the

darker tone of strip 3. The general result of these double contrasts is that the whole series or scale of tones presents the appearance of a number of hollows, although, in fact, the apparent hollows are perfectly flat spaces of shading or colouring. The effect is approximately represented in Fig. 14, where

Fig 14.



the real flatness of each tone of the six may be verified by covering up all the other spaces by a card. The same diagram of contrast of tone may be made more effective, by dividing a slip of card into several equal sections—say, six—by faint pencil lines, and then giving all six a light wash of Indian ink. Next, when this is dry, five sections receive a second similar wash. Afterwards the same process is repeated until the third section has received three washes, the fourth section four, the fifth section five, and the sixth section six. In carrying out the process, all sections, except those being submitted to the operation of washing, should be hid from view. Without this precaution it is difficult to secure a flat tint in each strip. If a series of pieces of grey paper of the same colour, but of different tones, are obtainable, they may be used in the construction of the same figure. They should be of equal size, and be pasted close together on a strip of cardboard; or a strip of glass or gelatine may be so arranged as to present at one end one thickness of the material, and the other end six or more thicknesses. On looking through the series, especially if a piece of white enamel glass, or a sheet of white paper, be placed behind, the effect of simultaneous contrast of tone will be clearly perceived. It is scarcely necessary to state that the tones of any particular colour may be used as well as grey to illustrate this kind of contrast. Its characteristic effect is not seen unless the contrasting tones differ considerably in intensity, and are in close contiguity or absolute contact.

Contrasts of colour are always more or less complex in character. There is, to begin with, the actual or objective difference between two colours, and then, superadded to this, we have certain subjective modifications, of an ocular or mental kind, which all contrasted colours produce. Further than this, it is rare to find any contrast of colour in which the effects of contrast of tone are not likewise present. We shall have to speak in a future lesson, and with considerable detail, of the practical results of all the circumstances which affect contrast of colours, and so now we merely introduce this subject by a few words on the successive and simultaneous contrast of colour.

If the eyes have steadily regarded some coloured object, and then look at a colourless object, that object will assume a colour complementary to that of the former, or will present an image of that object in the complementary colour. If the second object be itself also coloured, but differently from that first viewed, then the complementary colour will mingle with that of the second object, and modify its proper colour accordingly. But even a third case of successive contrast may occur. Supposing we look steadily at a series of pieces of scarlet cloth, one after another being placed before us; the eye, fatigued with the repeated calls on its perception and appreciation of scarlet, becomes incapable of estimating the series of identical specimens, and reports the last specimen to be duller than the first. The eye has become less appreciative of red, and more appreciative of the other colours. It sees less red, and more green than before. This green mixes with the red of the later specimens of cloth, dulling and modifying them. The eye may be rested and restored to its proper condition by gazing upon a piece of green cloth, when its power of appreciating red will once more return.

The simultaneous contrast of colours was first thoroughly worked out by the French chemist, Chevreul. It is the most fertile of all the laws of colour in the elucidation of the actual phenomena of contrasts, and in the suggestion of new combinations. When two coloured objects are seen at the same time, they usually mutually affect each other both in colour and tone. A yellow object, for example, placed close to a blue one, will appear as if it inclined to orange, while the blue object will seem to incline towards violet. The reason of this, on the assumption that yellow, red, and blue are the primary colours, is that the eye looking at yellow becomes less able to appreciate it, and sees the remainder of the primary colours, red and blue, that is, violet. This violet mixing with the contiguous blue colour tinges it with a faint trace of red. So with the blue object: the eye looking at the blue becomes less able to appreciate it, and sees the remaining primaries, yellow and red, or orange, the complementary of blue, which orange is imparted to the yellow, giving it a reddish hue. But blue and yellow differ much in their respective value as regards tone. The luminous and brilliant yellow becomes still more brilliant by contact with the richer and deeper blue, which itself is at the same time deepened, so that under ordinary circumstances these two colours afford a combined example of simultaneous contrast of tone and colour. But two complementary colours, such as red and green are presumed to be according to the common theory, do not modify one another's colour by contiguity. Theoretically, they contain the three constituents of white light, and the eye perceives no deficiency or excess of any coloured elements in the combination. So red and green merely enhance each other's characteristics when in contact. Thus it is with orange and its complementary blue, and with other pairs of complementary colours.

By placing strips of coloured paper together, a few of the chief phenomena of simultaneous contrast may be easily observed. We here give a list of some of the modifications of hue which coloured surfaces seem to undergo when placed in contact in pairs :—

Red	inclines to	violet.	Orange	inclines to	yellow.
Red *with* orange	,, ,,	yellow.	Orange *with* violet	,,	blue.
Red	,, ,,	violet.	Yellow	,,	orange.
Red *with* yellow	,, ,,	green.	Yellow *with* green	,,	blue.
Red		orange.	Yellow		orange.
Red *with* blue	,,	green.	Yellow *with* blue		violet.
Red	,,	orange.	Green		yellow.
Red *with* violet	,,	blue.	Green *with* blue		violet.
Orange	,,	red.	Green		yellow.
Orange *with* yellow	,,	green.	Green *with* violet		red.
Orange	,,	red.			green.
Orange *with* green	,, ,,	blue.	Blue *with* violet		red.

TECHNICAL DRAWING.—XVI.

DRAWING FOR MACHINISTS AND ENGINEERS.

Fig. 172.—This study is intended as an exercise in the use of the set-square of 60°.

Having constructed the containing rectangle, draw diagonals by means of the set-square resting on its shortest side on the T-square. All lines drawn against the hypothenuse of the set-square in this position will be at 60° to the horizontal lines and at 30° to the perpendiculars.

Now divide the base into the required number of equal parts, and draw lines from them parallel to both diagonals. This is done by turning the set-square. These lines will cut the perpendicular sides of the containing figure, and from the points thus obtained lines parallel to the diagonals may again be drawn as before.

To test the correctness of your work as you proceed, (1) Draw the horizontal line A B, which should pass through all the intersections at that height.

(2.) Draw the perpendicular C D, which should pass through all the intersections at that distance from the side.

(3.) Join any two of the points on a line drawn, as A B, and on E F construct two equilateral triangles; the apex of the one should be on the intersection G, and the other at H.

If the drawing does not fulfil all these conditions, there is something incorrect in the construction; and as the error would cause all the work based upon this original figure to be inaccurate, it is advisable to rub it completely out and start afresh. The most economical plan is, therefore, to work with the utmost care in the early stages, on which all the subsequent operations are based.

Fig. 173 is another design for a cast-iron grating, as an application of the foregoing study.

Having carried your work up to the stage shown in the last lesson, it becomes necessary to mark the width of the cross-bars.

Now in Fig. 170 this was done by setting off half the required thickness on each side of the intersection; but it will be evident that in the present instance this would not answer the purpose, as the lines intersecting are not at right angles to each other, and therefore the measurement set off on them would not give the correct width. Therefore, at any point (as *a*) draw a line at right angles to one of the cross-lines, and on this, on each side of the intersection, set off the half-width of the bars—viz., *b*, *c* —and through these points draw the required lines cutting the cross-lines in *d* and *e*. This length, therefore, may be set off from each of the intersections, and the required widths of the bars will thus be obtained. The centres for the circles are, of course, the intersections of the primary lines.

If a large circle is to be drawn, the inking-leg of the compass should be bent at the joint to allow of both the nibs of the pen touching the paper. If this is not done, the outer edge of the circle will be ragged. For small circles, bow-compasses are necessary. These, which have been already described (page 12), are small compasses with a neat handle at the top, by means of which they may be twirled round between the finger and thumb with the greatest ease. The best kind are made with joints in both legs, by means of which the steel point and the pen or pencil can be made upright, and thus far better work is secured. For still smaller circles "spring-bows" are used. These are very small and refined instruments, which open by means of a spring instead of a joint, and are regulated by a screw; they are

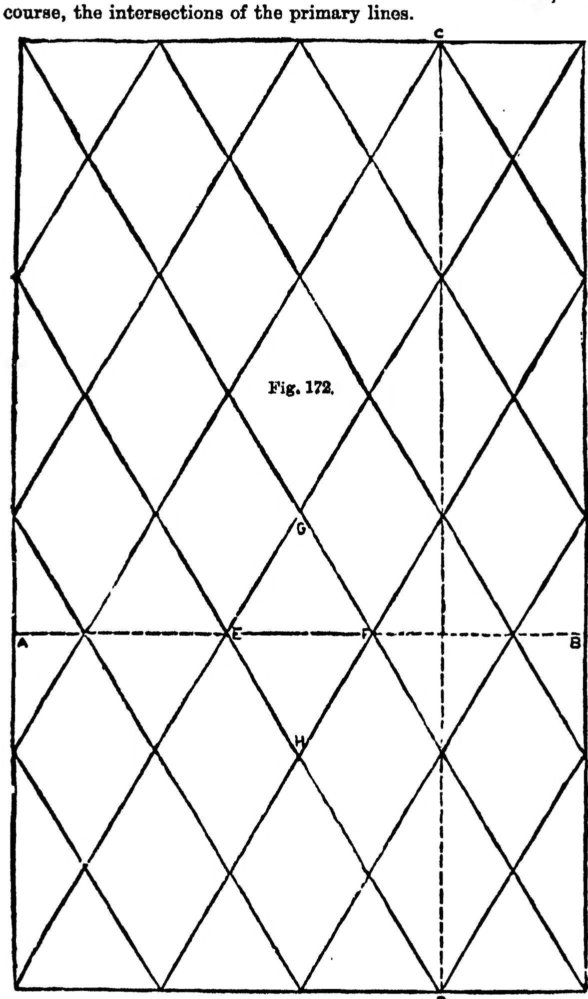


Fig. 172.

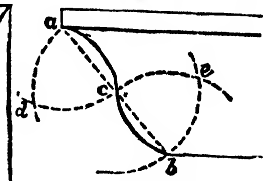


Fig. 182.

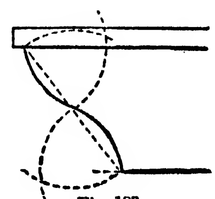


Fig. 183.

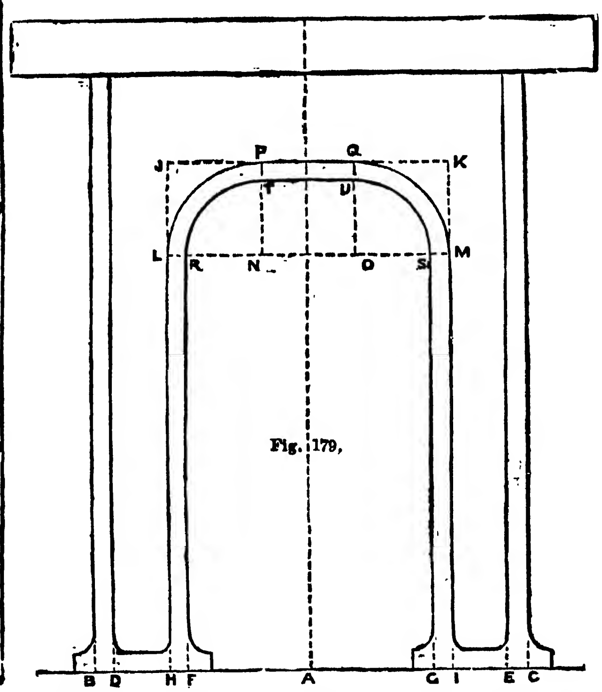


Fig. 179.

Figs. 174, 175, 176, 177.—These figures are simply intended to give practice in drawing concentric circles. The greatest care is necessary in this operation. The compass should be held loosely between the forefinger and thumb; the pressure on the steel point should be so very little that scarcely a mark is made on the paper. If by carelessness or pressure the paper is penetrated, the hole will be made larger as each circle is drawn, and of course the centre becomes no longer true. Thus the circles will not be parallel to each other, nor will the curve on ending meet the starting-point.

As concentric circles are of constant occurrence in mechanical drawing, it is important that the student should acquire the power of drawing them with the utmost precision and facility. The pencil-leg should be allowed to trail over the paper, and where numerous concentric circles are required it will be found in many cases unnecessary to pencil them; the radius of each may be merely marked on a line drawn through the centre, and the circles themselves can then be at once drawn in ink.

only sold in the better class of boxes, but a set of bow-compasses (three) can be purchased in separate small cases.

Fig. 178.—This study is designed to afford practice in joining arcs. The first line to be drawn in this case is the horizontal. On this describe a semicircle, A B. From the point where the semicircle meets the straight line (viz., B), set off the radius viz., B C), and from C describe the next semicircle on the opposite side of the line, carefully observing that the semicircle starts accurately from B, and that the joint is effected without any thickening, the curves running into each other so as to form one smooth wave-line. When the student can accomplish this, the drawing of a wave-line of a given breadth may be attempted.

Having drawn the centre line as above, set off as the radius on each side of B half the required breadth—viz., B E and B F; then with radius extending from the centre to each of these points in turn describe the semicircles required. Joining curves to straight lines occurs frequently in mechanical drawing, and this is therefore made the subject of the following study.

Fig. 179.—The object here represented is a portion of the framing of a small "table engine."

Having set off from the centre line, A, the half-width of the framing, A B and A C, erect perpendiculars. Draw the horizontal surface at the top and the edging D, E.

Now set off from A the distances F and G, for the width of the opening, and from A set off also A H and A I, so that F H and G I may be equal to B D and E C, the edging of the framing.

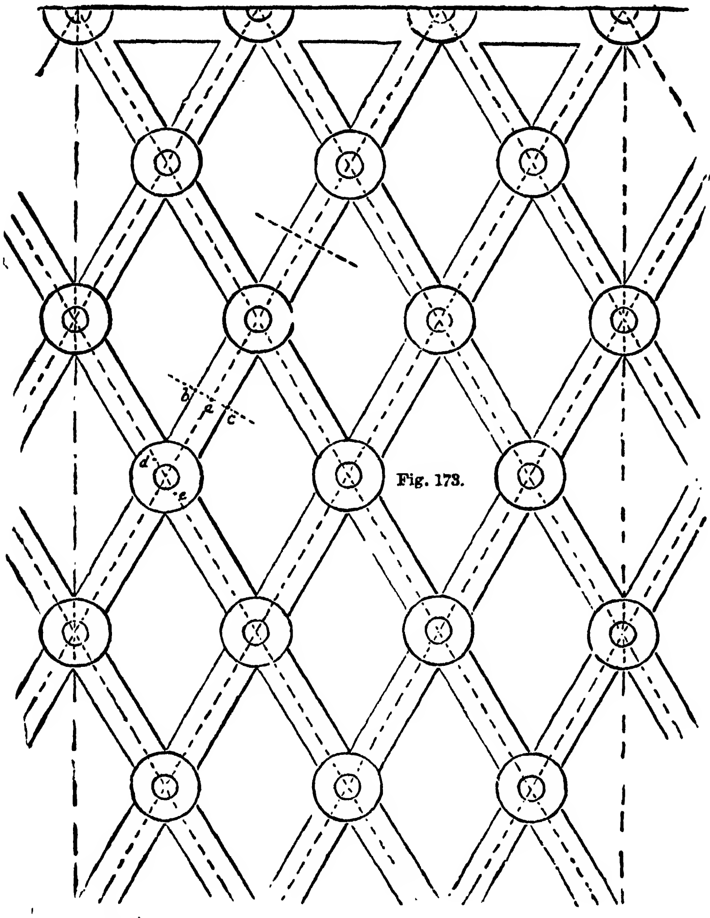


Fig. 173.

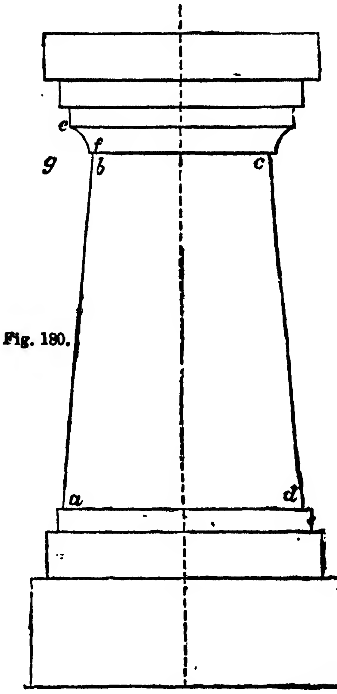


Fig. 180.

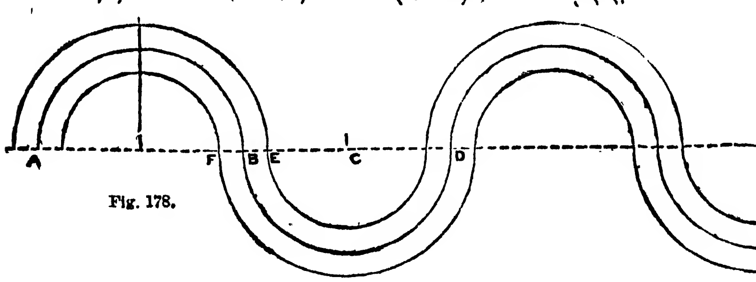


Fig. 178.

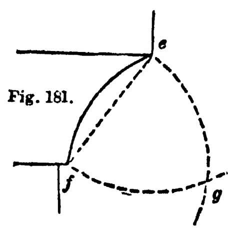


Fig. 181.

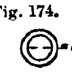


Fig. 174.

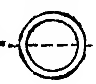


Fig. 175.

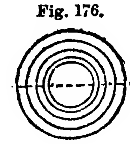


Fig. 176.

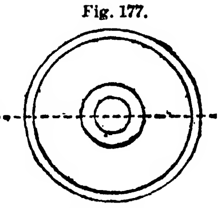


Fig. 177.

From H I G F erect perpendiculars, and at J K and L M draw horizontal lines.

From L and M set off L N and M O equal to L J or M K, and at N and O erect perpendiculars, cutting J K in P and Q.

From N and O, with radius N L or O M, describe quadrants joining L P and M Q. From N and O describe quadrants, with radius N R or O S, cutting N P and O Q in T and U.

Join P Q and T U, which will complete the framing.

The manner in which the curves at the foot of the framing are obtained being precisely similar to those above, no instructions concerning them are deemed necessary.

Observe.—When curves are to be joined to straight lines, *draw the curves first*, as it is easier to draw a straight line to meet a curve than the reverse.

Fig. 180.—This is an elevation of the pillar supporting the "governor," from the same small engine. It is supposed that but little trouble will be found in drawing this figure, as far as the straight portions of it are concerned.

Draw the ground line and central perpendicular, on which set off the heights for the horizontals. When these have been drawn, the widths are to be set off from the centre line. The points *a b* and *c d* having been joined, it only remains to describe the curve at *e f* and that on the opposite side. This curve is the arc which is formed by using the apex of an equilateral triangle as the centre, and the side of the triangle as the radius. This part of the drawing is worked out on a large scale in the next example (Fig. 181).

From *e* and *f*, with radius *e f*, describe arcs cutting each other in *g*; then from *g*, with the same radius, describe the arc *e f* as required.

Fig. 182 is the Cyma Recta moulding, and Fig. 183 is the Cyma Reversa. Both of these are of frequent occurrence in the

framing of machinery, and the mode of constructing them is therefore introduced here.

Draw a line between the points which are to be connected by the curve, as *a b* (Fig. 182), and bisect this line in *c*. From *a*, *c* and *c*, *b* describe arcs cutting each other in *d* and *e*; these will be the centres for the two parts of the curves, which must glide smoothly into each other at *c*. The form of curve may be varied by moving the point *c* either higher or lower, or taking a shorter or longer radius with which to describe the arcs.

AGRICULTURAL DRAINAGE AND IRRIGATION.—VI.

By J. Wrightson, Professor of Agriculture, Royal School of Mines.

COST OF DRAINAGE, ETC.

Land drainage under ordinary circumstances can hardly be spoken of as a very complicated process. The reasons which account for its marvellous effects, the changes it induces in the soil, the discussion as to the proper depth, distance, and direction of the drains, and the practical advantages which follow its adoption, are all fertile subjects. The mere description of the process of laying the pipes, however, need not detain us long. We have already devoted some attention to this portion of the subject, and it now remains for us to consider some difficulties which the practical drainer will encounter. Where the land is very wet, it is occasionally difficult to keep the trench open, in which case support must be given to the sides by boards and struts until the tiles are laid. Sometimes a quicksand is met with, upon which it is impossible to lay tiles, as they would speedily sink out of regular line. Under such circumstances, a layer of straw (according to Mr. Wilson, of Edington) or a narrow board must be used in order to give support to the tiles until they have time to act on the surrounding mass of soil, and render it dry and firm.

Tree and hedge roots are another source of danger. In order to avoid this, no drain should be laid nearer than five or six yards to a fence, unless special precautions are taken for preventing the entrance of root-fibres. Thorns are sometimes placed over the tiles in such drains to prevent this occurrence, and, in other cases, close-fitting collars are used at every joint so as to secure them from the entrance of roots.

It is occasionally necessary to carry a drain across a watercourse, and when this is required it may be passed underneath with the assistance of a few feet of iron piping.

Another difficulty frequently presents itself in obtaining a good outfall. Ditches which receive drainage water ought to be strengthened and deepened so as to offer the least possible resistance to its passage. Where the land to be drained is situated on a river-bank, it is sometimes difficult to contrive a suitable outfall for three or four feet drains. In such cases the main drain must be run parallel with the stream such a distance as to ensure an outfall for the higher-lying land. Landfast stones and rock also are frequent obstructions in cutting drains, but this is a difficulty which gives way before extra labour. If the rock be of a porous character it may occasionally be made use of as a vent for surface water. This plan is frequently followed in chalk and other districts where the nature of the soil will allow of it. The water is brought by ordinary drains to a low point or focus, where a well is sunk down into the rock, and thus the water is discharged into the great reservoir which underlies the formation.

The complete aëration of the soil is one of the principal functions of drains. It is, therefore, by no means a matter of surprise that the idea of "air drainage" should have been maintained strongly by many agriculturists. All draining, so far as it admits air, and cannot act unless air is admitted, is air drainage, but the advocates of this system wish to go further. They found an able exponent in the late Mr. S. Hutchinson, agent to the late Earl Brownlow. An idea of this method may be best obtained by reference to Mr. Hutchinson's experiments as recorded in Vol. IX. of the *Royal Agricultural Society's Journal*. He there makes the following statement: "The field to which I refer is in the occupation of Mr. Strafford, of Marnham, near Newark-upon-Trent, and consists of ten acres of strong loamy soil, resting upon a clay subsoil. It was underdrained by Mr. Strafford in 1843, by twenty-five parallel drains, two feet deep and five yards apart, each discharging into a covered outfall at the bottom of the field. In the autumn of 1846 it occurred to me that this being a shallow-drained field, presented a good opportunity for experiment. I divided it into five compartments, (see Fig. 11), each containing five of the drains. With the two outside and the centre compartments I did not interfere. Into the two other compartments I introduced what I called an air-drain, *a′ a′*, across the upper ends of the five drains, in each case, to join them together. I then connected the air-drain so cut with the adjacent open ditch at the top of the field, in order to increase the natural circulation of air through the ordinary drains." This experiment was successful, and subsequently both Mr. Strafford and Mr. Hutchinson were struck with the benefit following the introduction of the air-drains, when the land under their influence was compared with the neighbouring compartments not so treated. With a view to test the accuracy of these observations, the produce per imperial acre was accurately ascertained, both in wheat and turnips, and the result showed a palpable advantage in the *air-drained* plots. The prescribed method is exceedingly cheap, and may be resorted to without appreciably increasing the expense. Upon some soils an air-drain may be required in order to facilitate the egress of water; in others the porous character of the soil will allow a sufficient circulation of air without any additional help.

We now approach the consideration of the cost of drainage. This will vary with the expense of digging the trenches, their depth, the distance between them, and the price of tiles. The cost of digging three-feet drains through homogeneous clay soils is often estimated at one penny per linear yard, but where stones and rock occur this price may be indefinitely increased.

The distance between the drains resolves itself, so far as cost is concerned, into a mere question of the numbers of rods or chains per acre; and the price of tiles is very dependent upon that of coal. Where this is abundant, 2-inch tiles (internal diameter) may be obtained at from 17s. to 20s. per thousand, and 3-inch tiles at about 30s. per thousand. The following tables, taken from Wilson's "British Farming," embody much valuable information upon several of the points touched upon.

TABLE SHOWING THE NUMBER OF RODS OF DRAIN PER ACRE AT GIVEN DISTANCES APART, AND THE NUMBER OF PIPES OF GIVEN LENGTHS REQUIRED PER ACRE.

Intervals between the drains.	Rods per acre.	12-inch pipes.	13-inch pipes.	14-inch pipes.	15-inch pipes.
18 feet		2420	2234	2074	1936
21 ,,	125⅘	2074	1915	1778	1659
24 ,,	110	1815	1676	1555	1452
27 ,,	97⅘	1613	1489	1383	1290
30 ,,		1452	1340	1244	1161

From the following table we learn the expense of draining land will, under ordinary circumstances, vary from £5 to rather more than £8 per acre, according to the distance between the channels. There are, however, other important elements connected with the materials used for forming the drains, the depth of the drains, and the tenacity or rockiness of the soil. With these ever-varying conditions, the cost may easily exceed or be less than the above estimates. Thus Mr. Stephens gives a list of prices ranging from £2 7s. 6d. to £9 10s. per acre. The first case was that of a soil described as overlying irregular beds of gravel or sand, and irregular open strata, the material used being broken stones. In such a case the distance between

the drains might be increased easily to forty feet with good effect. Contrasted with this minimum expenditure, we have the high figure above given, in which the soil was described as "hard till" or clay, when it was found requisite to place the drains ten feet apart, and where stones were used as the material.

TABLE SHOWING THE COST OF DRAINING PER ACRE AT VARIOUS INTERVALS BETWEEN THE DRAINS.

	18 feet apart.			21 feet apart.			24 feet apart.			27 feet apart.			30 feet apart.		
			d.	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
Labour—cutting and filling at 6d. per rod	3	13	4	3	2	10	2	15	0	2	8	11		4	0
Material—pipes for minor drains 18s. per 1,000 . .	2	5	9	1	19	2	1	14	3	1	10	6	1	7	5
Haulage 2 miles and delivery in fields at 2s. 6d. per 1,000 .	0	6	4	0	5	5	0	4		0	4	3	0	3	9
Pipe-laying & finishing at 1d. per rod.	0	12	2	0	10	6	0	9	2	0	8	2	0	7	4
Superintendence—foreman . .	0	5	0	0	5	0	0	5	0	0	5	0	0	5	0
Extra for mains .	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0
Iron outlet pipes and masonry, and extra labour . . .	0	1	6	0	1	6	0	1	6	0	1	6	0	1	6
Total . .	7	6	1				5	11	8	5	0	4	4	11	0
Add for collars if used . . .	1	2	10	0	19	7	0	17	1	0	15	3	0	13	8
		8	11	7	6	0	6	8	9	5	15	7	5	4	8

The Marquis of Tweeddale gives the expense of tile-draining as varying from £4 to £10. The lower price is for cutting two-feet drains thirty feet apart at a cost of ½d. per yard, and the higher figure is for draining three and a-half feet deep, fifteen feet between the drains, and at a cost of more than 1d. per yard (Stephens). Draining by means of the mole plough may be accomplished at a cost of from £1 per acre, according to a recent report upon Mr. Ruck's farm, at Braydon Manor, to £1 8s. and £1 10s., according to the nature of the soil, and the depth and distance. When, however, circumstances vary so widely, it is a difficult matter to fix any definite limit to the expense, almost every field requiring a different treatment to the last, and each case having its own special requirements with regard to depth, distance, and cost of labour.

The effect of drainage in increasing the produce is, in some cases, exceedingly marked. Instances are not wanting in which the agricultural value of the land is entirely owing to this improvement. In very many cases one quarter extra per acre of wheat, and a proportional increase in the yield of other crops, is looked upon as the advantage which may be expected. Again, looking at the benefits of land drainage from a general point of view, we find farmers willing to pay 6 per cent. upon money thus expended by their landlords, and at the end of the lease this per-centage is incorporated in the ordinary rent-charge, thereby showing that the improvement is looked upon as permanent. Among the best examples of improvement are those collected by Mr. Stephens in the "Book of the Farm." There we are told that in the case of land belonging to Mr. Dalrymple of Cleland, Lanarkshire, one field of eighteen acres cost £5 9s. per acre to drain. Previously this field had been occupied with whins and rushes, and had been let for 12s. per acre; but after draining, the wheat off one portion of it brought £13 per acre, the potatoes off another part £15 15s. per acre, and the turnips off the remainder £21 per acre. Mr. James Howden, Wintonhill, East Lothian, asserted years ago that, although drains should cost as much as £7 per acre, yet on damp heavy land thorough drainage would repay from 15 to 20 per cent. upon the outlay. A farmer in Lanarkshire, who thoroughly drained one-half of a four-acre field, and left the other half undrained, planted the whole field with potatoes. From the drained half he realised £45, whilst the undrained half only realised £13 per Scotch acre. It appears almost unnecessary to multiply instances. We conclude by citing the results obtained on the Teddesley Hay Estate, the property of Lord Hatherton, where, after an expenditure of from £3 10s. to £4 per acre, the rental value of the land was increased in one case from 10s. to 27s. per acre, in another from 10s. to 35s. per acre, in a third from 16s. to 33s., and in a fourth from 8s. to 22s. per acre. Such examples, although matters of fact, may possibly mislead unless it be remembered that the ordinary result is much less striking, and that the more modest but satisfactory return first spoken of will be a more usual measure of the direct advantages derived from land drainage.

No one now denies the advantage of draining arable land, although some persons hold that it is possible to overdrain even this. With regard, however, to pastures, there has been a considerable amount of discussion, many farmers considering that the amount of grass is diminished by the operation. Such seasons as 1868 and 1870 are well calculated to try the truth of such opinions: it was, therefore, exceedingly judicious in Mr. J. C. Morton, at the close of 1868, to request answers from correspondents in various parts of England upon the results, during the long-continued drought, of drainage upon pastures. In answer to the query, "Are there instances known to you of differences, as regards productiveness, during so dry a season, between drained and undrained land either arable or pasture?" Mr. Paget, of Ruddington, "confesses that where the land had been very recently drained, and consequently the grasses proper to dry land were not fully established, they did not afford quite so much 'keep' as the corresponding undrained land; but as soon as the rain fell in August, the advantage was on the side of the drained land. Those meadows which had been long drained had the advantage throughout." This is an instructive case, and explains why, in some cases, drainage has temporarily lowered the yield of grass upon pasture lands. Mr. Wortley, of South Collingham, Newark, says, "I must say that, according to my experience, there is some foundation for the popular belief that a certain kind of grass land is injured by under-draining; that is to say, the inferior plants which previously made a show, if they did little more, are destroyed by the drainage, and they are very slowly replaced by better, if the land is left to itself. With such exceptions, however, my belief has always been that the draining of wet land, whether arable or grass, increases the productive power, even in such seasons as the last." Mr. James Rawlence also says, "I quite think with you that more corn or grass have been grown on drained than on undrained land, except on grass land which had been drained the previous autumn, in which case the aquatic plants all died out from the long drought and heat, and the more nutritious grasses had not time to fill up their places." These concurrent testimonies to the effect of drainage upon grass lands are very conclusive, and reconcile apparently contradictory observations, it being evident that although the ultimate effect of drainage upon grass land is beneficial, yet there is a period of trial between the dying out of sedges and water-grasses and the prevalence of a sweeter and better herbage.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—IV.

DEFINITIONS CONCERNING POLYGONS.

ALL figures having more than four sides are called polygons, and are distinguished by names denoting the number of their sides and angles—thus:

A Polygon of 5 sides is called a	Pentagon.
	Hexagon.
	Heptagon.
	Octagon.
	Nonagon.
10	Decagon.
11	Undecagon.
12	Duodecagon.

When all the sides of a polygon are equal, and all its angles equal, it is called *regular*.

When they are not equal, the polygon is said to be *irregular*.

By drawing lines from the angles of a regular polygon to the centre, the figure may be divided into as many triangles as the polygon has sides. In the regular hexagon these triangles will be *equilateral*, but in all other regular polygons they will be isosceles.

The methods of constructing the various polygons having been given in "Lessons on Geometry" in THE POPULAR EDUCATOR,

it is only necessary in this place to give one or two, in order to show their application in mechanical drawing.

To inscribe a regular pentagon in a circle, by a special method (Fig. 40).

Draw the diameter A B, and bisect it, or divide it into two equal parts in O. At O erect a perpendicular, O C. Bisect O A in the point D, according to the method indicated in the figure.

From D, with radius D C, describe an arc cutting A B in E.

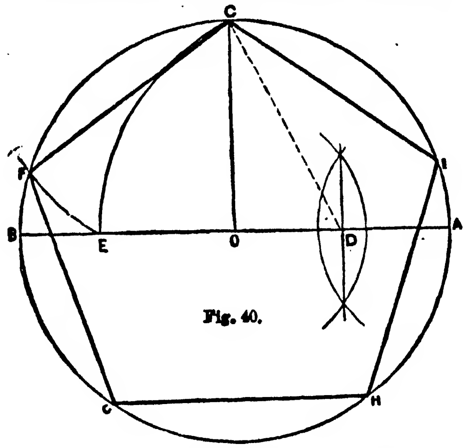


Fig. 40.

From C, with radius C E, describe an arc cutting the circle in F.

Draw C F, which will be one side of the pentagon.

Set off the length C F around the circle in the points G, H, I.

Draw lines F G, G H, H I, and I C, which will complete the figure.

Application of the foregoing principle in the construction of Gothic tracery (Fig. 41).

Draw a circle, divide it into five equal parts, and draw the radii O A, O B, O C, O D, O E. Bisect one of the radii, and set

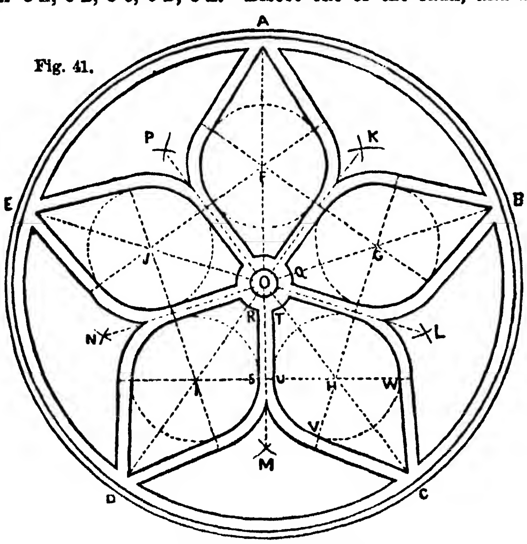


Fig. 41.

off the half on each of them in the points F, G, H, I, J. Join these points, and a regular pentagon will be formed.

Bisect the sides of this pentagon by the lines O K, O L, O M, O N, O P.

Draw a small circle in the centre, and another, Q, concentric with it.

From Q to the sides of the pentagon draw lines parallel to O K, O L, etc., at a small distance on each side of them—viz., R S, T U, etc.

Produce the sides of the pentagon indefinitely from F, G, H, I, J, and with radius H U describe circles cutting the produced sides of the pentagon in V W and the corresponding points.

Draw V C, W C, and similar lines from the other circles, and the remaining lines will be parallel to and concentric with those already drawn.

To construct a regular hexagon on the given line A B (Fig. 42).

From A and B describe arcs cutting each other in O.

From O, with radius O A or O B, describe a circle.

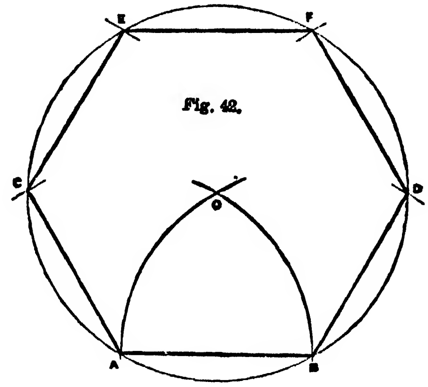


Fig. 42.

The radius with which a circle is struck will divide it into six equal parts; therefore set off the length O A, which is equal to A B, around the circle—viz., C D E F.

Join these points, and a regular hexagon will be formed.

To inscribe a regular hexagon in a circle.

Find the centre of the circle, set off the radius around it, and join the points.

Example 1 *of inscribing a hexagon in a circle.—To draw a simple fly-wheel* (Fig. 43).

Draw the circles A and B, representing the outer and inner edge of the rim.

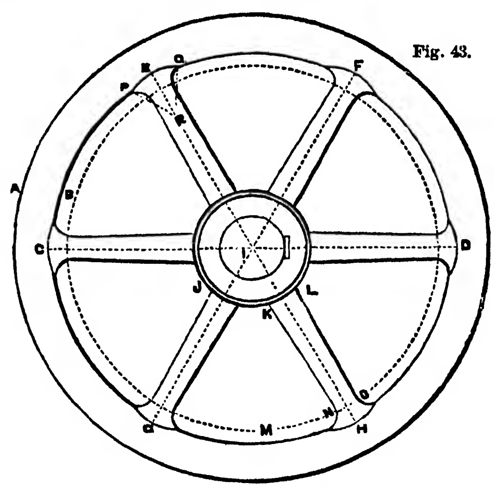


Fig. 43.

Divide the circle B into six equal parts, and draw the diameters C D, G F, E H.

Next draw the circles I and J, representing the end of the shaft and the boss, or central part of the wheel; the small parallelogram at the side of the inner circle represents the "key," by which the wheel is held on the shaft.

On the edge of the boss set off equal distances, K L.

Draw the circle M, and on it, on each side of the radii, set off distances rather less than K and L—viz., N and O.

Draw the sides of the arms, K N and L O, etc.; and with any convenient radius describe the small arcs connecting the arms with the rim at N and O.

The length P Q set off from P and Q on the radius, will give the point R, which is the centre for striking the arc, caused by the elliptical arm meeting (called *penetrating*) the elliptical rim.

Example 2 of the application of the hexagon in mechanical drawing (Fig. 44).

In this drawing of a nut and bolt, the plan—that is, the appearance it would have if your eye were directly over it, and you looked down upon it—is to be drawn first.

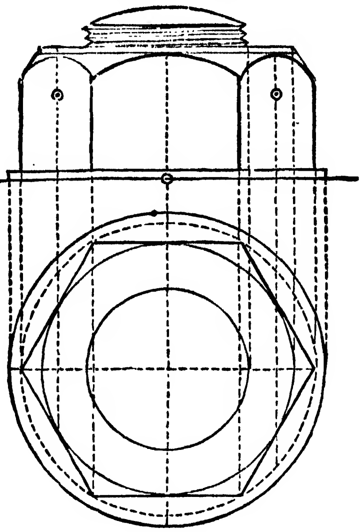


Fig. 44.

The two largest circles being described, the inner one is to be divided into six equal parts, and a hexagon inscribed in it.

Perpendiculars drawn from each of the angles of the hexagon will give the projection of the widths of the sides of the nut.

Within the equilateral triangle, A B C, *to inscribe six equal circles* (Fig. 45).

Draw the lines B D, A F, and C E, bisecting the sides and angles of the triangle, and intersecting each other in O.

Bisect the angle O A E, and the point (G) where the bisecting line cuts C E, will be the centre of one of the three isosceles triangles, into which the equilateral triangle has been divided.

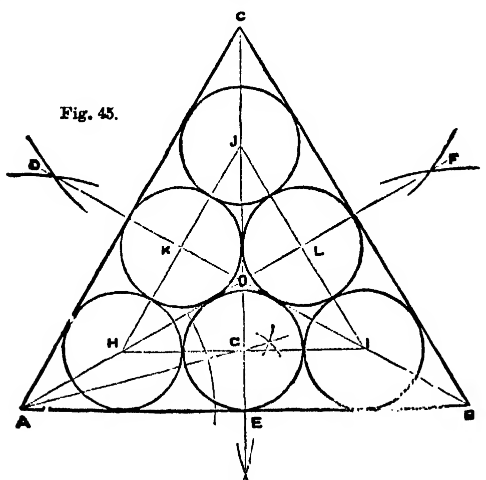


Fig. 45.

Through G draw H I parallel to A B, and from H and I draw H J and I J, cutting B D and A F in K and L.

From G H I J K and L, with radius G E, draw the six circles.

To inscribe three equal circles in a circle (Fig. 46).

At any point, as A, draw a tangent, and A G at right angles to it. From A, with radius O A, cut the circle in B and C.

From B and C draw lines through O, cutting the circle in D and E, and the tangent in the point F (and in another not given here, not being required). Bisect the angle at F, and produce the bisecting line until it cuts A G in H.

From O, with radius O H, cut the lines D C and E B in I and J.

From H, I, and J, with radius H A, draw the three required circles, each of which should touch the other two and the outer circle.

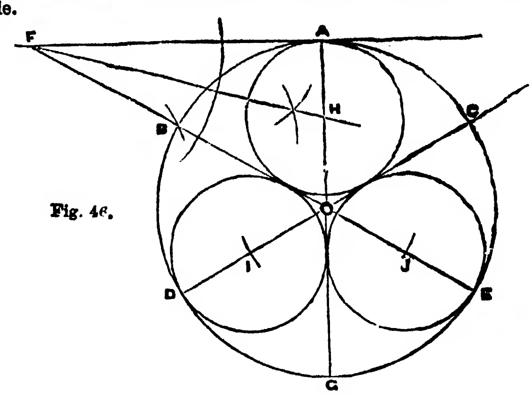


Fig. 46.

To inscribe in an equilateral triangle, A B C, *the three largest circles it will contain* (Fig. 47).

Draw A G, B F, and C E, bisecting the angles and sides of the triangle, and intersecting in O.

Bisect the right angle A E O.

Produce the bisecting line until it cuts A G in H.

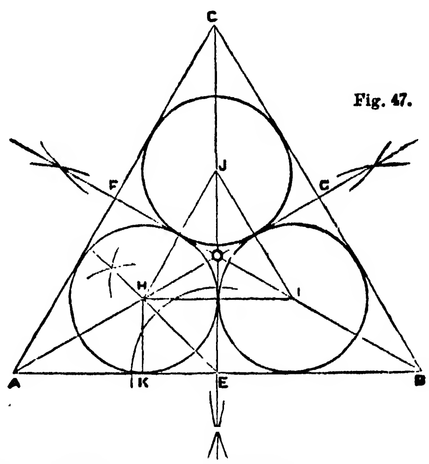


Fig. 47.

Draw H I parallel to A B, H J parallel to A C, and I J parallel to B C.

From H, I, and J, with radius H K, draw the three circles, each of which should touch the other two, and two sides of the triangle.

NOTABLE INVENTIONS AND INVENTORS.

V.—CLOCKS AND WATCHES (*concluded*).

CLERKENWELL has long been noted as a clock-making parish. The most extensive establishment here has workshops for every branch of manufacture: as the brass-casting, the wheel and pinion cutting, the case-making, and the movement-making. Wooden clocks are made on the confines of the Black Forest, by peasant families—the export of clocks from Baden alone amounting to £1,000,000 sterling. Of American clocks, in New Haven 50,000 brass eight-day clocks are made in a year at one factory; the wheels and plate-holes are all stamped, and the maintaining power is a spring, in place of the gradual fall of a heavy weight. In electrical clocks, the indicator has a clock-face and an index, or hand, and the communicating disc is moved round by the oscillation of a pendulum, kept going by electricity; thus one clock, by a wire, communicates its own time to any number of clocks at any distance, kept in perfect unison by the action of only one pendulum. Horological electricity also drops time-balls, fires time-guns, and exhibits an hourly signal from the

parent electro-magnet clock at Greenwich Observatory, to correct any error in the great clock at Westminster. Illuminated clocks date from the "fire-clock" of Martinelli, in 1663, and in an old German work we find designs for illuminated dials; in one the light is placed behind a transparent dial and opaque figures, which are reflected, much magnified; in another, the light issuing from a lantern is so arranged as to fall on, and be continued to, the dial of a clock.

It is curious to find, in the year 1869, the good citizens of Beauvais placing in its cathedral a monumental clock, composed of 14 different movements, and 90,000 pieces (weighing 35,000 lb.), and costing £5,000. The body of the clock is 36 feet high, of carved oak; it has a figure of the Supreme Being, and the twelve apostles, in enamel; the main dial (there are 50 in all) has a figure of the Saviour—the largest enamel existing. The pendulum weighs nearly 1 cwt., and is moved by a steel ball weighing but the thirty-second part of an ounce, this movement impelling the fourteen others. The other dials indicate days of the week, movements of the planetary bodies, sunrise and sunset, seasons, signs of the zodiac, duration of daylight and night, saints' days, months, phases and age of the moon, time at principal cities, solstices, movable feasts, age of the world, year of the century, bissextile years, longitudes, tides, eclipses, etc.

In the seventeenth and eighteenth centuries several very curious clocks were constructed. Among those were Grollier's model of a ball ascending and descending inclined planes, spiral grooves, and others swallowed by serpents; lizards ascending columns, with the hours marked on them, and mice moving on a graduated cornice. The "invisible clock" at Vauxhall Gardens, in 1822, is thus explained:—"An hour-hand pointed to the hours on a transparent dial, without visible connection with mechanism. This was effected by having two pieces of glass placed together, the hand being fixed in the centre of one of them, which, turning round once in twelve hours, by motion produced at a tangent, pointed to the hours marked on the other piece of glass, which was immovable."

Amongst the uses of time-keepers we find that by means of clock, the Danish astronomer, Roemer, discovered that the eclipses of Jupiter's satellites took place a few seconds later than he had calculated, when the earth was in that part of its orbit the farthest from Jupiter. Speculating on the cause of this phenomenon, he concluded that light was not propagated instantaneously, but took time to reach us; and from calculations founded on this theory, light has been discovered to dart through space with a velocity of about 192,000 miles in a second; thus the light of the sun takes eight minutes to reach the earth. Sir G. B. Airy has ascertained the variation of gravity at the surface and interior of the earth, by descending to the bottom of a deep mine, and the result of his computations is, "supposing a clock adjusted to go true time at the top of the mine, it would gain $2\frac{1}{4}$ seconds per day at the bottom; or it may be stated thus: that gravity is greater at the bottom of a mine than at the top, by $\frac{1}{19190}$th part."

Time-pieces with springs as the maintaining power (and now called watches) were imperfect machines, going with even less precision than an old clock. They had only an hour-hand, and most of them required winding twice a day. A watch differs from a clock (says Dr. Arnott) in having a vibrating wheel instead of a vibrating pendulum; and as in a clock gravity is always pulling the pendulum down to the bottom of its arc, which is its natural place of rest, but does not fix it there, because the momentum acquired during its fall on one side carries it up to an equal height on the other—so in a watch, a spring, generally spiral, surrounding the axis of the balance-wheel, is always pulling this towards a middle position of rest, but does not fix it there, because the momentum acquired during its approach to the middle position from either side carries it just as far past on the other, and the spring has to begin its work again. The balance-wheel, at each vibration, allows one tooth of the adjoining wheel to pass, as the pendulum does in a clock; and as a spring acts equally well, whatever be its position, a watch keeps time whether carried in the pocket or in a moving ship. In winding up a watch, one turn of the axle on which the key is fixed is rendered equivalent, by the train of wheels, to about 400 turns or beats of the balance-wheel; and thus the exertion, during a few seconds, of the hand which winds up, gives motion to twenty-four or thirty hours.

The invention of the coiled spring in the watch dates from the close of the fifteenth century. It is claimed for Nuremberg, then famous for watches, but the priority is much disputed. Their introduction into England is equally uncertain. The watch of Abbot Whiting, dated 1536, is of accredited antiquity; and Count D'Albanne's silver watch, of English workmanship, is dated 1529. Henry VIII. had a watch that went for a week; Anne Boleyn possessed another, as well as a small gilt clock, now in Windsor Castle. Edward VI. had, in 1542, a "watch of iron." Mary Queen of Scots possessed a death's head and a skull watch; one in a case of crystal, coffin-shaped; and another in which a piece of catgut supplied the place of a chain; but all these were foreign watches. Queen Elizabeth had a large collection of watches. A watch was found upon Guido Fawkes; and of this period is a curious oval-shaped watch in a silver case, ornamented with mythological figures. The English watch-makers of the City of London were incorporated in 1631. In 1635 the value of a brass watch was 40s. Charles I. possessed several watches. In 1658 was constructed the spiral, or pendulum-spring, invented by Dr. Hooke and improved by Tompion. Next, Juare, by applying the pendulum-spring, added (to the hour-hand) minute-hand and wheel-hand. He also added the repeating movement in watches; one of the first was presented by Charles II. to Louis XIV. of France. Juare also made repeating watches for James II. and William III. From 1698 all makers were compelled by law to put their names on their watches. In 1724 was invented the horizontal escapement by Graham, who also invented the mercurial compensation-pendulum. Graham's escapement has been superseded by the duplex, and more recently by the lever, which is the dead-beat escapement applied to a watch. At the beginning of the last century was invented jewelling the pivot-hole of watches, to prevent friction. Next, John Harrison, by his famous chronometer, discovered the longitude, for which he received from Parliament £20,000. Among his other improvements, are the gridiron pendulum and the expansion balance-wheel—the one to equalise the movements of a clock; the other, those of a watch, under all changes of temperature, by employing two different metals to form the rod of the pendulum and the circumference of the wheel, so that the contraction of the one exactly counterbalances the expansion of the other. Another of Harrison's inventions is the going fusee, by which a watch can be wound up without interrupting its movement. A time-keeper of greater simplicity than Harrison's was that of John Arnold, for which he and his son received the Government reward of £3,000; the extreme variation of this machine in twelve months has been thirty-seven-hundredths only. Arnold also made the smallest repeating-watch ever known, for which George III. presented him with 500 guineas. The next improver of the chronometer was Thomas Earnshaw; and in this state it has remained for the last century or so with scarcely any alteration.

Among the celebrated French watchmakers was Breguet, who paid some of his workmen thirty francs a day, and none less than a napoleon. He invented the touch watch, by which a spring touched at any time struck the hour and minute; one cost the Duke of Wellington 300 guineas.

Some years ago it was maintained that our common watch is, in many of its parts, a very ill-constructed machine. The train of wheel-work, which transmits the motion of the mainspring, for example, is contrived on faulty principles, and the long-used methods and engines were alike condemned. Mr. Dent has stated that every watch consists of at least 202 pieces, employing, probably, 215 persons, distributed among 40 trades—to say nothing of the tool-makers for all of them. It is next maintained that if we were then materially to alter the construction of the watch, all those trades would have to be re-learnt, new tools and wheel-cutting engines would have to be devised, and the majority of the workmen to begin life again. During this interval, the price of the instrument, it is asserted, would be enormously advanced.

Watch-making in England suffers much from overstrained competition; the annual importation of watches from Switzerland and the United States is very largely in excess of the number made at home.

In America watches are manufactured on a large scale by aid of machinery. We read of a manufactory with 250 hands, more than half of whom are females. The stamps and dies are

out by steam machinery, by which are effected the processes, also, of hardening and forming the barrels and chambers, coiling and fastening the mainsprings, gearing-wheels, and cutting their teeth; shaping pinions and axles, cutting escape-wheels, trimming and marking the porcelain dials, drilling and shaping the jewels, and adjusting and fitting together the various parts.

It has been confidently stated that the result of the introduction of machinery into the watch-making trade is already to be seen in the comparatively low price at which that necessary article is to be obtained; but hitherto the great drawback has been that machinery was unable to compete with hand-work in the extremely delicate manipulation of the watch. The difficulty, however, has been entirely obviated by an American invention, which, with the exception of the hair-spring, makes every portion of the watch with a nicety scarcely to be surpassed. One of the chief advantages of this is that each part, being made by a separate machine, can, in the event of damage, be supplied through the post to any part of the world.

THE ELECTRIC TELEGRAPH.—IV.

INTERRUPTIONS IN COMMUNICATION—MODE OF TESTING FOR AND LOCALISING FAULTS.

As we have already seen, any electric circuit is liable to various interruptions, which often cause serious inconvenience. It is therefore a very important matter to be able to discover the cause of the interruption, and, if it be an injury to the line, to find the exact place at which it exists, so that it may be repaired as promptly as possible. When any circuit is interrupted, the first thing to ascertain is whether the fault exists in the battery, the instruments, the office, or the line.

Suppose the clerk at any office presses the key of his instrument with a view of sending a message, but finds that his own needle is not affected at all, he at once knows that something is wrong. If his own battery or instruments are out of order, and will not act, that will fully account for the failure. His first duty, therefore, is to make sure that the fault is not in his own office. For this purpose the wire where it leaves the office should be temporarily connected with the earth-plate, so as to cut the line-wire and receiving station altogether out of the circuit, and a current should then be sent again. If now the instrument acts satisfactorily, the fault is either on the line or at the receiving station, and the reason why the current would not pass is that the circuit is interrupted at one of those places.

If, however, when earth is thus put on, the needle still declines to move, the fault is evidently in the office, and may be a faulty connection, or a failure of the instruments or batteries. The latter should first be tested by connecting their two poles with a galvanometer, and noting the deflection. Should this indicate that the battery is enfeebled or impaired, it should be replaced, or set in order. It not unfrequently happens that a single cell in the trough is working badly, and has entirely stopped the passage of the current generated by the rest. In this case the defective cell must be replaced, or else bridged over by making a good connection between the cells on either side of it.

If, however, the battery is in good order, the fault must be in the instruments or their connections, and its exact place may be discovered by affixing one end of a good wire to the terminal where the line-wire leaves the instrument, and having pressed down the key so as to send a constant current, bring the other end of the wire successively in contact with the different binding-screws or connections. As soon as the fault is passed, the needle will immediately be deflected, and thus the place of the interruption will be seen.

Sometimes the injury will be found to be a rusted or dirty connection; or sometimes, if inferior oil has been used in any part of the apparatus, the dust may have settled on it, and become hardened, so that in this way a faulty contact is produced. Too much care cannot be taken in ensuring the perfect cleanliness of all connections, as, even if the current passes at first, the surface, after the lapse of a little time, becomes more corroded, and a great amount of inconvenience and loss of time may be caused in discovering the exact place. A little of the best salad oil should be applied to the pivots and points by which a contact is made, as a safer connection is ensured thereby, and this oil will not harden sufficiently to injure the contact. The contact-plate should, however, be frequently wiped to remove the dust which may have settled on it. In this way any faults in the office are easily discovered, and for the most part they may without much difficulty be rectified, unless, indeed, the needle has become demagnetised, or there is some injury to the instrument rendering necessary its return into the maker's hands. More commonly, however, the fault exists along the line. An insulator may be broken, or the wires may be so slack as to come into contact with one another, or with some obstruction which carries away a part of the current.

As considerable inconvenience and delay are caused by such faults on important lines, it is usual to test them every day with a view of discovering any flaw before it is sufficiently developed to interrupt the communications. In these tests two things are ascertained—the degree of insulation, and also the amount of resistance which is offered to the passage of the current, as sometimes the wire may be well insulated, but a defective place in it may offer such a resistance as nearly to intercept a weak current. In the daily tests of the British Postal Telegraph lines a battery of 50 Daniell cells is used; but 100 or 200 cells are often used in testing faults of insulation in submarine cables.

A well-made galvanometer is the most important thing in testing a line. There are two different forms of this instrument in common use. In the more sensitive of these the needle is placed horizontally, being poised on a fine steel point. Friction is thus reduced to a minimum, and the only force to be overcome by the current is the directive influence of the earth's magnetism. The instrument is so placed that the needle may point to o on the graduated scale; the current is then applied, and the amount of deflection when the needle comes to rest is noted. This instrument is represented in Fig. 14.

In the other form of galvanometer, usually called the "detector," the needle hangs vertically inside the coils, a pointer being fixed on the same axis so as to indicate the position of the inner needle. In the more perfect instruments of this class, this outer needle is magnetised as well as the inner one, and is so mounted that its north pole shall point in the reverse direction to that of the inner one, and thus both are affected by the current round the coils, and the instrument is rendered much more sensitive. The lower end of the needle is slightly weighted, so that it hangs vertical when no current is passing. Hence this form of galvanometer is more used than the other, as it requires no adjustment of position. The graduated scale is placed above the needle, as seen in Fig. 15.

Without care the readings of a galvanometer may be misunderstood, for a deflection of 40° must not be taken as an indication that the current is just twice as strong as one producing a deflection of half that amount, or 20°. A special scale has accordingly to be provided for each instrument. In a well-made detector, the values of the degrees up to 30° were found very nearly to correspond with the strength of the current; above that the following results were obtained:—

40°	deflection represented a strength	equivalent to	44°
50°	,,	,,	65°
60°	,,	,,	93°
65°	,,	,,	150°

In another galvanometer, the values of the reading would probably differ to a considerable extent; it is necessary, therefore, for each to be graduated by actual trial.

The following is the simplest manner in which the daily tests for insulation and resistance are made:—Let A and B be the stations at the ends of the line. A puts a detector in his circuit, and then sends a current through it along the line, having first informed B, who for a short time, say two minutes, disconnects his line-wire altogether, so as to leave it completely insulated. The deflection of the detector during this period shows the amount of loss by imperfect insulation, and if this amount is above the daily average, it plainly shows some defect, as, for instance, a broken insulator. B then, for a similar period, connects his end of the line-wire to a good earth, through his own detector, and the results now obtained show the resistance to the current. A very weak battery should be employed for this purpose, since otherwise "full deflection" would almost certainly be obtained, even although a considerable fault existed. Only very rough tests can therefore be made in this way, and at all principal stations the resistances are accurately ascertained

by means of a resistance coil and a differential galvanometer. The last-named instrument consists of a magnetised needle mounted with two independent coils, each of which exerts the same influence on the needle. If, then, the current be made to pass round these in opposite directions, the needle will remain at rest, one coil exactly neutralising the effect of the other. In order to use this galvanometer, two passages are provided for the current from the battery; the resistance to be measured is made a part of one of these circuits, while in the

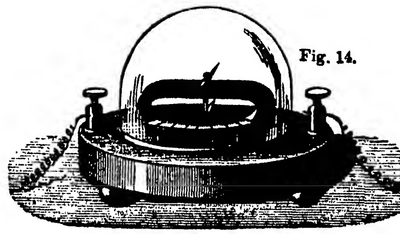


Fig. 14.

other is placed a series of resistance coils by which a known resistance can be introduced till it exactly balances the other, as shown by the needle remaining at zero.

The annexed diagram (Fig. 16) will render this more clear. B is the battery, from each pole of which there are two conducting wires. The one leads to the binding-screw A, whence the current passes round one coil to E, thence along the line-wire L, whose resistance is to be ascertained, returning either by the earth or by another wire whose resistance is known, or else similar to that being tested. The other battery wire leads to C, and from this the current passes round the other coil of the galvanometer to D, thence through the set of resistance coils R, and back to the other pole. Two courses are therefore open for the current, and it accordingly splits between them; the greater portion, however, passes along the route which offers the least resistance, and the needle is accordingly deflected by that. By means, however, of the various coils in R, the resistance in that circuit can be so adjusted as exactly to balance that of the line, which is thus ascertained. If the current returns from L by a wire similar to itself, the resistance must be divided by 2 to give that of each wire. If it returns by a wire of known resistance, that must be deducted to give the resistance of L. S is a "shunt" affixed to one of the coils of the galvanometer, so as to reduce the effect of the current upon it by providing a short path for the greater portion of the current. A peg is inserted between the pieces of brass, and offers $\frac{1}{9}$ or $\frac{1}{99}$ the resistance of the coil, round which accordingly only $\frac{1}{10}$ or $\frac{1}{100}$ of the current passes. The advantage of this is that by it a much smaller resistance coil is required, since one of 1,000 units may balance a resistance of 10,000 or

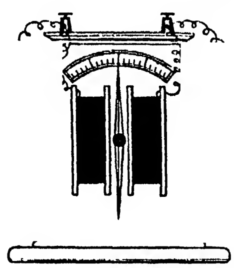


Fig. 15.

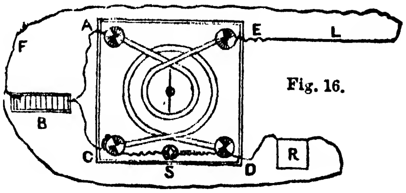


Fig. 16.

100,000 units, the proper shunt being employed. In this case the indicated resistances must of course be multiplied by 10 or 100.

When the test for insulation is being made, the further end of the line is disconnected, and the corresponding pole of the battery put to earth, as seen in Fig. 17. This circuit then can only be completed by the escape of a portion of the current from the line-wires to the ground, owing to imperfect insulation. In keeping a record of these tests, it is important to note also the state of the weather at the time of taking them, since this makes a material difference in the state of the lines.

We must now endeavour to explain roughly the manner of ascertaining the position of a fault in any line, when it has been ascertained that there is one. We must, however, first know the different kind of faults that are met with. The first is a total interruption of the circuit arising from a broken wire or some similar cause, in which case no current whatever passes. There may also be a partial want of continuity indicated by the signals at the receiving station being less distinct than usual; so much so at times as to be unintelligible.

Another defect is "earth" on the line—that is, a connection

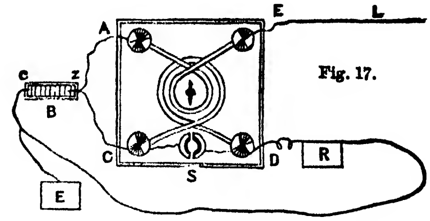


Fig. 17.

at some place between the line-wire and the ground, so that a greater or less portion of the current escapes. If the connection be a very good one, so that the whole of the current escapes, we have what is technically known as "dead earth." In this case the signals at the sending station are stronger than usual, since there is a shorter path for the current to travel along, but no signal whatever is received at the receiving station. When this happens, each station along the line should in succession transmit a current, and the interruption will evidently be beyond the last one from which a current is received. When it has been ascertained between which stations the fault lies, its place can be found by noting the resistance of that piece of line as compared with its usual resistance. If it be only half as great as usual, the fault is probably about mid-way along it, and so in proportion.

Partial earth occurs when there is a fault by which only a portion of the current escapes, and this is a more difficult fault to test for. The signals at the sending station are still unusually strong, since two return paths are open for the current, one by the fault, the other in the usual way. The signals at the receiving station are, however, weakened considerably.

The best plan of testing for a fault of this description will be understood by reference to Fig. 18, in which the battery, etc., are denoted by the same letters as before. If possible, a good wire, H, leading from the receiving station, should be used as a return wire, being connected to the faulty one at G. Let F be the place of the fault, and let the connections be made as shown. The current leaving c to the earth-plate will divide at F, a portion passing along by G, H, E, A, to z; the other portion passes through the resistance coils R, and so to z. If R were

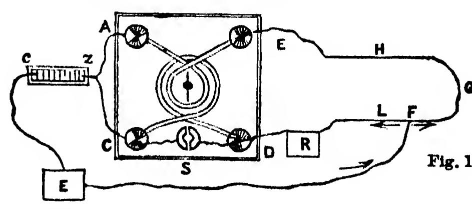


Fig. 18.

removed, the latter portion would clearly be the stronger, since it has the shorter distance to travel; by introducing a resistance, therefore, we can ascertain how much one exceeds the other, and from that we can calculate approximately the place of F. When this is done, there will probably be little difficulty in the line inspector ascertaining and repairing the damage.

Instead of the differential galvanometer, the Wheatstone Bridge, a similar arrangement, is also used for these tests. In this for the coils of the galvanometer A E and C D coils of wire of proportionate or equal resistance are substituted, and an ordinary galvanometer is connected between E and D. Then when the galvanometer shows no deflection, $\frac{AE}{CD} = \frac{L}{R}$. (Fig. 16.)

OPTICAL INSTRUMENTS.—III.

BY SAMUEL HIGHLEY, F.G.S., ETC.

DIAGNOSIS FOR SPECTACLES.

To ascertain what form of lens is needed to correct the defective vision of a patient, the optician or oculist must first determine the true nature of the defect—whether it be presbyopic, myopic, or hypermetropic; and if the person is not advanced in years, great care should be taken to ascertain whether or not the last defect exists, for by a faulty diagnosis great injury might be brought about through supplying unsuitable glasses. Again, it must be determined whether failing sight is due to optical defects of vision, or to those weaknesses of sight known as amblyopia and asthenopia, which are due to irritation of parts of the eye.

First, he must determine the patient's "acuteness of vision," as it is technically termed, by exercising the eye on Dr. Snellen's "Test Types." These consist of carefully-drawn, square, lithographed letters, whose limbs have a width equal to one-fifth of the letter's height, such being generally distinctly visible to a normal eye at an angle of 5′. These letters are arranged singly or in groups, and of increasing size, with a number attached to each, to indicate the number of feet at which the particular-sized letters must be placed from a normal eye, to subtend an angle of 5′ for their height; and, further, an angle of 1′ for the breadth of the thick strokes, for determining "the minimum angular magnitude of distinct vision" (which is taken at 1′).

These types range in size from the smallest letters, to be seen at 1 foot, to 3¼ inches in height, to be employed at 200 feet. Two diagrams are specially designed for testing the acuteness of vision at an infinite distance, that is, from 20 feet to 200 feet—one having black letters on a white ground; the other, similar letters, but white on a black ground. To normal eyes these seem nearly alike as to distinctness; but should the white letters on a black ground appear more distinct to the patient, a diminution of acuteness of vision is indicated, which probably results from diffuse light, arising from turbidity of the refractive media of the eyes. The distance from which the test-types can be distinctly recognised should be measured from the surface of the paper to the temple of the person under examination. These letters are grouped in irregular order, so that no help may be given to their recognition by juxtaposition with other letters, as would be the case were words employed; while, on the other hand, to attain, if possible, more uniform distinctness, certain letters that might lead to confusion with similar ones are omitted. Thus every care is taken to ensure a perfect and independent recognition of those letters without any extraneous help.* The degree of acuteness of vision (V) is expressed by the relation of the distance at which the letter is actually seen (d) to that at which the letter is apparent at an angle of 5′ (D).

$$V = \frac{d}{D}.$$

If No. I. is distinctly seen at a distance of one foot, and No. XX. at twenty feet, then d and D are equal, and accordingly it follows that

$$V = \frac{1}{I} = \frac{20}{XX} = 1;$$

or, in other words, there is normal acuteness of vision.

If, on the other hand, No. I. is only distinct at six inches from the eye, and No. XX. at ten feet, then d is less than D, and

$$V = \frac{\frac{1}{2}}{I} = \frac{10}{20} = \frac{1}{2}.$$

If No. XV. can only be recognised at a distance of five feet, then we get the following equation :—

$$V = \frac{5}{XV} = \frac{1}{3}.$$

If d should be greater than D, and No. XX. be thus visible at a greater distance than twenty feet, then the acuteness of vision is more than the normal average.

* An English edition of Snellen's "Test Types" is published for the benefit of the Netherlands Ophthalmic Hospital, by Messrs. Williams and Norgate.

An investigation of 281 cases of emmetropic eyes at different ages gives the following results :—

At from ten to twenty years	$V = \frac{2}{20}$
At thirty years	$V = \frac{22}{20}$.
At fifty years	$V = \frac{18}{2}$
At sixty years	$V = \frac{14}{20}$.
At eighty years .	11

So, it will be observed, the normal acuteness of vision decreases with age.

Besides these tests by jumbled groups of letters, the person may be tested by reading in different-sized type, but such experiments must not be identified with the recognition of isolated letters, for the reason previously stated; but in other respects reading is a more difficult test, because the letters of words, as ordinarily printed, are very close together, hence more confusing for immediate recognition.

For testing by reading, fluency is chiefly to be regarded, for with a contracted or interrupted visual field reading is less fluent. It is obvious that this test can only be tried on persons of fair education.

Snellen's *reading tests* are printed in type as nearly as possible uniform with his *letter tests*, and the following numbers of his types correspond in height with the less scientific system of "test-types" of Professor Jäger, which, however, have been principally used in this country.†

No. I. of Snellen's	= No. 1 of Jäger's Test-Types.		
II.	,,	5	,,
III.	,,	7	,,
IV.	,,	11	,,
V.	,,	13	,,
VII.	,,	14	,,
XVIII.	,,	18	,,
XXVII.	,,	19	,,
XXXVIII.	,,	20	,,

A good series of *reading test* may be formed of short paragraphs set up in the following well-known printer's types :—No. 1, "brilliant;" No. 2, "pearl;" No. 4, "minion;" No. 6, "bourgeois;" No. 8, "small pica;" No. 10, "pica;" No. 12, "great primer;" No. 14, "double pica;" No. 16, "two-line great primer;" No. 18, "canon;" No. 19, "four-line condensed;" No. 20, "eight-line Roman." An eye with normal acuteness of vision ought to be able to read Nos. 18, 19, and 20 of these types at a distance of twenty feet; but a person may be so amblyopic as not to be able to read the largest of Snellen at any distance. In such cases we may try whether the person is able to count fingers at different distances, or whether he can distinguish light from darkness by placing him at six feet from an argand gas-flame in a dark room, then turning the light up and down slowly; or, if this fails, from light to sudden darkness, and back again. If the patient cannot distinguish between such extremes, he must be "stone blind."

We must next test for the "range of accommodation" the patient's eyes possess, by first determining the "near-point" and then the "far-point," which may be expressed by th following formula :—

$$1 - 1 - 1$$

in which p represents the (*proximate*) nearest point of distinct vision, and r (*remote*) the farthest point of distinct vision, and $1 \div A$ the range of accommodation. For this purpose we employ an optometer, which consists of a carrier for a test-plate, and an adjustable scale that will give the exact distance between the face of the plate and the cornea of the patient's eye. The test-plate may consist of a paragraph set up in "Brilliant" or "Pearl" type, which corresponds to Nos. 1 and 2 of Jäger's reading tests; or of a little frame, 7-8ths wide in the opening, divided vertically into six parts by five fine black wires or horsehairs; or of a black

† Copies of Jäger's test-types may be obtained of the Secretary at the Royal Ophthalmic Hospital, Moorfields.

plate, pierced with little holes from 1-20th to 1-6th of a line in diameter, behind which a background of ground-glass is placed: these rapidly emit rays, and lose their round form, if not perfectly focussed on the retina. The adjustable scale may be a winder measuring tape, the ring of which is looped on to the handle that supports the test-plate; or it may be a shoemaker's rule, the fixed end of which is cut down and notched to receive the patient's eye, the test-plate being fixed to the sliding upright; or it may be a specially-designed piece of apparatus, consisting of a graduated brass rod, mounted on a firm telescopic foot by a shifting-hinged joint, on which a frame that carries the test-plate works freely up or down, and can be clamped at any desired position by means of a milled-headed screw. Whatever the arrangement, the test-plate should, as Donders has pointed out, be moved steadily up to, or away from, the eye under examination, for "ordinary individuals accommodate for their farthest point only, when they actually look at a distant object, and for their nearest only, when they very distinctly see an object approaching, whose diminishing distance they meanwhile observe and follow in their imagination. Then, by the effort actually to see the object distinctly as long as possible, the greatest power of accommodation is excited."

On sliding along the reading-test towards the eye, we soon find the nearest point at which the text can be read off. With the wire-test, the wires only appear sharply defined when the eye accommodates itself perfectly to them; directly there is a deviation in this (the frame being too near or too far from the eye), the wires seem indistinct, thicken, or as if surrounded with a halo; or even double-coloured images of them appear in the transparent intervals, as a white wall or the sky should in this test be used as a background. The same may be remarked in regard to the test-holes, for they rapidly lose their round form and emit rays when the eye is not in perfect accommodation with them. It will be readily seen that much depends upon the intelligence of the person under examination in appreciating the distinctness of the wires or the sharp form of the holes; therefore the reading-test is, as a rule, the most readily applied; for it is oftentimes absurd to what a distance persons will maintain that the wires and holes seem well defined; while, by moving the reading-test alternately nearer to and further from the eyes, we can readily ascertain with exactitude both the near and the far point of distinct vision.

If to this optometer we add an arm fitted with a six-inch convex lens, the far-point may be ascertained in all cases. If for an eye (with suspended accommodation) we have to move the test-plate to six inches' distance to secure distinct recognition, it is emmetropic; if nearer to the eye than six inches, it is myopic; if further off, it is hypermetropic. The systematic employment, in the optometer of Von Graefe, of a convex lens of only six inches focus, presents advantages over those of longer foci, as it brings the normal eye to a condition that is very nearly myopic, and so in a state more favourable for comparison. By employing an optometer of the kind last described, the far (r') and the near (p'), *thus found*, stand in such a relation to the patient's real far (r) and near (p) point, that the rays coming from r' are refracted by the lens as if they proceeded from r, and those from p' as if they emanated from p.

In the normal eye (with 6-inch convex) r' would lie at six inches from the eye, for rays from an object at six inches' distance falling on the lens would be rendered parallel by it, and would consequently impinge upon the eye as if they came from an infinite distance or the normal far-point. The near-point (p') would lie at *about* three inches, for this varies according to age.

If (with 6-inch convex) we find the far-point (r') lies at six inches, and the near-point (p') at three inches,

$$A = \frac{1}{3} - \frac{1}{6}$$

the eye is then emmetropic.

If (with 6-inch convex) we find that $r' = 5$ inches, and $p' = 3$,

$$A = \frac{1}{3} - \frac{1}{5}$$

the eye is then myopic, for it is not adjusted for the normal far-point (six inches), but for a nearer one, the rays from which impinge in a divergent direction upon the eye.

If (with 6-inch convex) we find that $r' = 8$ inches, and $p' = 3$ inches,

$$A\ \frac{1}{3} - \frac{1}{8}$$

the eye is then hypermetropic, for its far-point lies beyond the normal far-point, namely, six inches. It has been stated above that these determinations may be made *for an eye with suspended accommodation.* Now in practice this is rarely met with, except in cases where the power of accommodation is paralysed ("*paralysis of accommodation*," as it is technically termed); but we have the power of producing such a state of rest artificially, by the application of a solution of atropine (gr. iv. to ℥j) two hours prior to making the trial. As the effects of atropine last for some days, I need hardly say that the ordinary optician would not be justified in using this agent on his customers, and that its employment must be confined to the practice of the medical oculist. Moreover, as decided cases of presbyopia and myopia are readily determined by optical tests, it is only in cases of suspected hypermetropia, or for determining the whole amount of a patient's hypermetropia, that atropine is needed.

But when there is reason, from the form of the eye (see p. 160), together with complaint on the part of the patient of constant fatigue in the organs of vision, to suspect the existence of hypermetropia, the optician may make the following trial. Try the patient's eye on No. XX. of Snellen's test-types, at twenty feet distance, or on a paragraph set up in type of this size

Canon

If the eye is emmetropic, it will read this at the distance specified; and a hypermetropic eye will most probably do the same, *unless* the hypermetropia be very great, or *its accommodation has been paralysed by atropine!* Now try the patient with spectacles glazed with 20-inch lenses on the same object at the same distance; if the eye is emmetropic, it will no longer be able to read the test; while if it be hypermetropic, it will read it with greater facility than before.

In extreme hypermetropia the eyes may not be able to read the test with 20-inch lenses, but can without them. Thus assimilating to the characteristics of a normal eye makes its diagnosis by optical tests extremely difficult; but a suspicion of its existence should be created when fatigue in the eye is constantly complained of; and as the question must then be settled by ophthalmoscopic indications, it becomes the duty of the optician to direct the patient to consult an ophthalmic surgeon; for the diagnosis and mode of treatment must be medical as well as optical.

In testing for the range of accommodation, it is necessary to try both eyes of the patient; for it will often be found that the two eyes of the same individual may possess a difference in accommodative power. In other cases we may find that the near-point may be normal, but the far-point approaches nearer than an infinite distance to the eye, which might be mistaken for an indication of myopia; or the far-point may be normal, and the near-point abnormally distant from the eye; or both near and far point may have changed their normal position, and have become approximated to each other.

We may also meet with a dislocation of accommodation, without any diminution in its range.

In making trials for the far and near point, we bear in mind that in the normal eye its far-point lies at an infinite distance (symbolised by ∞), so that parallel rays are united on the retina when it is adjusted for its far-point, while its near-point lies at from four to five inches from the eye, though even a near-point of seven inches is not to be regarded as sufficiently abnormal to amount to a defective state of vision.

In testing for the near-point we may find that one person will clearly distinguish the test-plate as close as three inches, while another cannot do so nearer than thirty inches. This indicates that the one has the power of increasing the convexity of his crystalline lens by a quantity equivalent to a 3-inch glass lens; while the second can only do so to an extent equivalent to a 30-inch glass lens; and we say that the accommodation of the first equals 1-3rd, and that of the second equals 1-30th.

TECHNICAL DRAWING.—XVII.

DRAWING FOR MACHINISTS AND ENGINEERS.

FREE-HAND DRAWING.

THE great importance of Free-hand Drawing to artisans has already been insisted upon, and a few examples in this branch of the subject will be given in this part of our lessons in "Technical Drawing," in order to show the kind of practice which is deemed advisable for machinists and engineers.

Our workmen have laboured under the mistaken idea, that so long as they could manage to measure and rule the lines from a copy with some degree of neatness, they were learning Mechanical Drawing. Nor were the teachers of the period immediately preceding the present competent to give them better instruction; for whilst qualified mechanical draughtsmen were not teachers, the teachers were artists, but not engineers. It was only when the Government Department of Science and Art undertook the systematic training of masters of Schools of Art—in which not only ornamentists and designers, but artisans generally were to be taught—that this branch of the subject began to receive proper attention, and was made a portion of the certificate examination; and not only is Linear Drawing by means of instruments taught, but the artisan is shown how to sketch from objects and to draw curves by hand; in fact, an enlarged view of the whole subject has been given, of which the fruits are daily becoming more obvious. The early training of foreign artisans has in this respect been superior to ours; and in the different exhibitions which have been held in this country and on the Continent, workmen were to be seen with their note-books busily employed in collecting information, and sketching the appliances connected with their peculiar walks of industry. Such notes and sketches, however roughly done, must be a source, not only of great usefulness, but pleasure to them.

Drawing, too, constitutes a universal language, which to artisans is a matter of the utmost importance; for by its means they can illustrate the form of an object in an infinitely less period of time than by words, to persons who may not be able perfectly to understand the language of the country; in fact, in the words of Sir Joshua Reynolds, "the pencil speaks the tongue of every land."

The machinist must remember, too, that in making drawings from actual measurement, the instruments are not in the first instance employed. All the implements used are the pencil and the "two-foot rule." The draughtsman makes a rough sketch entirely by the hand and eye, measures the various parts, and jots down the measurements in his sketch. After this he reduces the whole to the required scale, and proceeds to make his mechanical drawing.

As the lessons proceed, the student will be taught how to draw from objects seen perspectively. In commencing, however, the practice is confined to a few well-known objects placed so as to present only one surface to the eye of the spectator, and which can thus be drawn as mere elevations. In the first instance tools have been chosen, because the student is supposed to be well acquainted with their forms; thus, when he has sketched them, he will, as it were, be able to check his own work, and this may, it is hoped, lead him to try his hand on other objects; he will thus gain power and courage, and will be gradually led on to attempt (and to succeed in) higher things.

Drawing, in addition to its use as a universal language, is a means of strengthening the powers of observation, and, viewed in this light, it is a study of the greatest importance to workmen. To "*look at*" is not necessarily "to *observe*"—the latter term implies a careful examination of all the parts of an object, an accurate study of the points in which they differ from others, and their peculiar adaptation to their special purpose. In this drawing materially aids the student; for as each line of the object is followed, and compared with others, the mind is led to appreciate forms which would have escaped casual observation. The artisan will understand what is meant by this accuracy in observing special forms, if he calls to mind the differences which exist in even the same tool, when adapted for the various branches of handicraft. Take, for instance, such a simple tool as a hammer, and note the variations in form between the joiner's hammer, the fitter's hammer, the smith's hammer, the watchmaker's hammer, etc.; and it must be remembered that all the differences visible are of importance in the work in which the tools are to be used.

Fig. 184 is a sketch of a pair of compasses, such as is commonly used by machinists; it is here given, in order that the student may compare it with Fig. 25, page 68, which represents the same instrument used by the carpenter or joiner; and the difference will at once become evident. The method of drawing this object being in the main the same as that already given, is not repeated here. The student is reminded, too, that even in the same branch there are different forms of the same instrument—such as the compass with a quadrant and thumb-screw, and, for finer work, the spring-dividers; all have their peculiarities, and each will afford a subject for careful study.

Fig. 185 is a machinist's screw-driver, which will afford another study as to the differences in form when compared with the joiner's screw-driver, given in page 48. In this subject, too, the horizontal centre line A B having been drawn, the directions given in connection with the former subject are to be followed.

Fig. 186 represents a pair of callipers. Draw the perpendicular A B, and the circles at the top. Next sketch the curve from C to B, and adopt as a general rule that the curve on the left side should be drawn first when another is to be drawn to balance it; for if the right curve were sketched first, the hand would cover it when drawing the other, and thus the balancing would be rendered difficult.

When this curve, then, has been satisfactorily sketched, draw a line, D, across the widest part, and from F mark off the length F E equal to F D; the curve G B may then be drawn.

The inner lines to H and I are to be straight, and from these points the inner curves to the ends of the legs are to be drawn. It will be seen that, although the callipers are open, it is advisable to continue the curves in the first instance to B, although only wanted as far as J, K.

PRACTICAL GEOMETRY.

A fair knowledge of Practical, Plane, and Solid Geometry is of the utmost importance in mechanical drawing, in which the various constructions are applied, and it is therefore assumed that the student has worked through the majority of the figures in lessons in "Practical Geometry applied to Linear Drawing" and "Projection," which are intended as stepping-stones to the present lessons.

A few additional figures, however, bearing immediately on the subjects to be delineated, are here given, and the student will find that the application of these and other scientific methods will not only enable him to work with greater accuracy than any empirical means, but will save much time and trouble.

Figs. 187 and 188 show the liability to inaccuracy where a straight line has to be drawn to touch a circle. In Fig. 187, owing to the great radius of the circle, it is almost impossible to say which is the exact point of tangent; and in Fig. 188 it will be seen that, owing to there being no definite point at which to draw the straight line, it often occurs that it is so drawn as to cut off a portion of the circle.

Fig. 189 shows two pulleys rotating in the same direction by means of a band wrapped round both.

Now it will be clear that this band must touch the circles, without cutting off any portion of the circumferences, and must therefore be composed of true tangents.

Fig. 190 will remind the student that a true tangent is at right angles to the radius drawn from the point of tangent.

Having, therefore, set off on a straight line, A B (Fig. 189), the centres of the two circles at their correct distance apart, and having described the circles, draw diameters at right angles to A B. These will cut the circles in C D and E F, thus giving the exact points which are to be joined by the straight lines of the connecting band.

Fig. 191.—*To draw tangents to a circle from a point,* A, *lying without it.*

From A draw a line to the centre of the circle, B.

Bisect A B in C.

From C, with radius C B, describe an arc cutting the circle in D and E.

Draw A D and A E, which will be the required tangents; and it will be seen that the radii drawn from D and E are at right angles to these.

Fig. 192 shows the method of drawing tangents to two circles of different diameters.

Draw a straight line through the centres A and B of the circles, and produce it.

Draw any radius in either of the circles, as B C. In the second circle, draw a radius, A D, parallel to B C.

From C draw a line through D, meeting the line of centres in E.

The point E is therefore "a point lying without the circle," from which it is required to draw a line which shall be a tangent to both circles, therefore proceed as in the last figure—viz.:—

Bisect the line joining E and A in F.

From F, with radius F A, describe an arc cutting the circle A in G and H. Draw the radii A G and A H.

From B draw the radii B I and B J parallel to A G and A H.

Then straight lines drawn from E through and H will meet the circle B in I and J, and will thus be tangents to both circles.

Fig. 193.—This figure shows a driving - band crossed, by which means the pulleys are made to rotate in opposite directions.

Join the centres of the circles by the straight line A B, and draw diameters at right angles to this line, cutting the circles in C, D and E, F.

Draw C F cutting A B in G.

Bisect A G in H.

From H, with radius H A, describe an arc cutting the circle A in I and J.

Draw the radii A I and A J.

In the circle B draw the radius B K parallel to A I, and the radius B L parallel to A J.

Draw I K and J L, which, passing through G, will be the two lines required, each being tangential to both circles.

Before proceeding to the next lesson it may be mentioned that the student should keep up the constant practice of free-hand drawing, since it is only by practice that any degree of proficiency can be obtained. Amongst other subjects which might furnish good practice for free-hand drawing, are the following: a vice, a hand-vice, a hammer, a pair of pliers, a pocket-knife with one of its blades open; and then the student is advised to try his hand on parts of machines, as a hanger, a plummer-block, a crank, a cone-pulley, etc. Many of these subjects for study are to be found in the lessons in "Technical Drawing," and these may serve as guides; but in the present stage the work is to be done by free-hand only.

Again the student is urged to sketch very lightly at first, so that he may have an opportunity of reviewing his drawing as a whole before "lining in;" he can then easily rub it out and repeat the lines. In starting any subject which, like the callipers and compasses, is equally balanced, a vertical line should always be drawn. Now, some persons have from habit acquired the power of drawing horizontal lines more easily than upright ones, and therefore turn the drawing-board in order to draw the line parallel to their chest. This is a very bad practice, and should be carefully guarded against in young people.

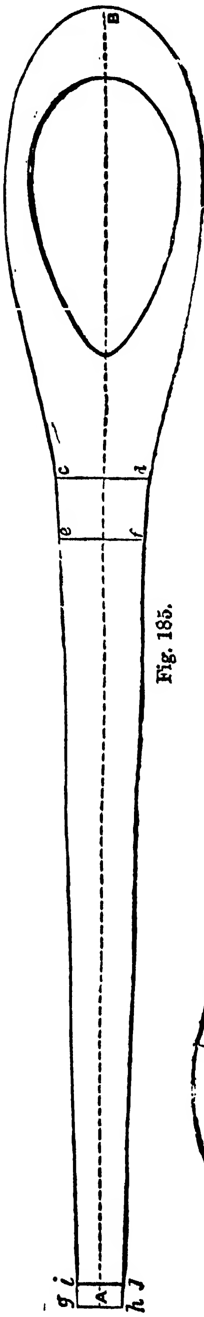
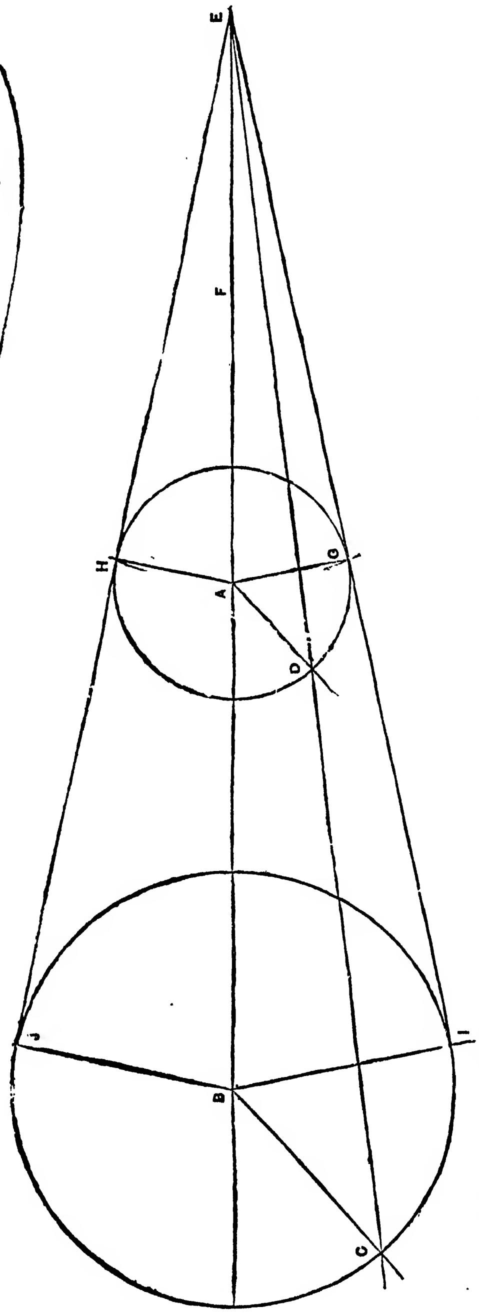


Fig. 185.



Nor should the board be turned in drawing the object itself. The left side should be drawn first, and then balanced by the right, as already described. The drawing should then be held up, and the faults in balancing will at once become visible. It is best in sketching, whether the form is to be regular or otherwise, to generalise the whole before drawing any single part definitely; by this means much time is spared, for the student will often, when he pursues the opposite plan, find he has bestowed much care on drawing one portion of the subject, which when he comes to draw the rest, he finds too large, too small, or otherwise useless. A few touches, scattered as it were over the paper, will, however, enable him to judge of the general proportions of the whole, and of the position and space which should be occupied by the details.

To do this, it is best to look upon the whole subject in the first instance as one mass, and having sketched this, find the points where it might be divided into two or three smaller portions; not absolutely drawing the lines, but marking off the spaces. By this method room will be found for all the parts, and it will be easy to get all the proportions correct.

Having thus generalised, some fixed point should next be decided upon, and this should then be sketched with some care, so that other parts dependent upon it may be properly placed. Thus proceeding, the minor details will follow in their places.

It is a good plan for artisans to repeat their drawing in ink with a steel pen, instead of using the pencil; in doing this the pen must not be pressed on, as in the down-strokes in writing, but the student must endeavour to keep a fine equal line throughout. In some cases a flat-wash of colour may be thinly and lightly spread over the representation of the object, which practice will in some degree prepare the student for the lessons to be given further on.

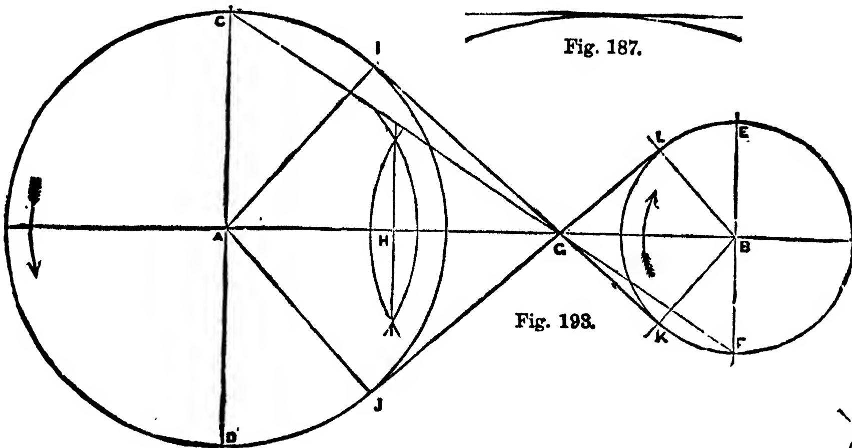


Fig. 187.

Fig. 193.

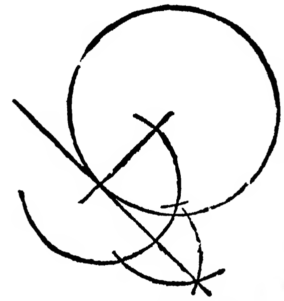


Fig. 190.

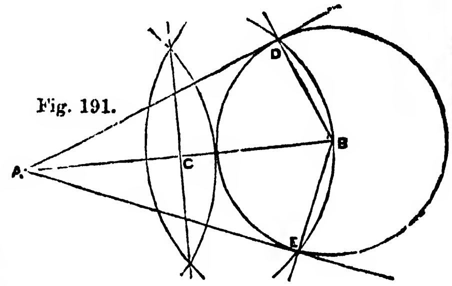


Fig. 191.

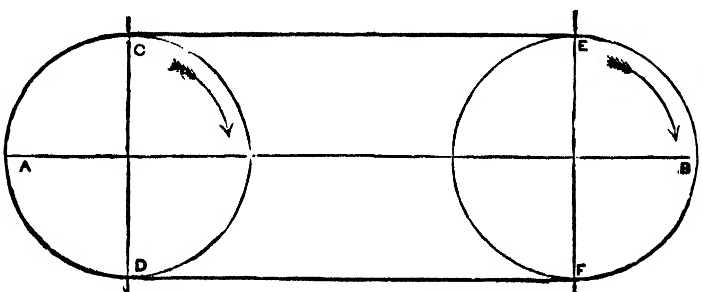


Fig. 189.

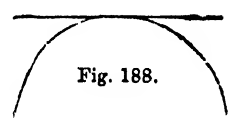


Fig. 188.

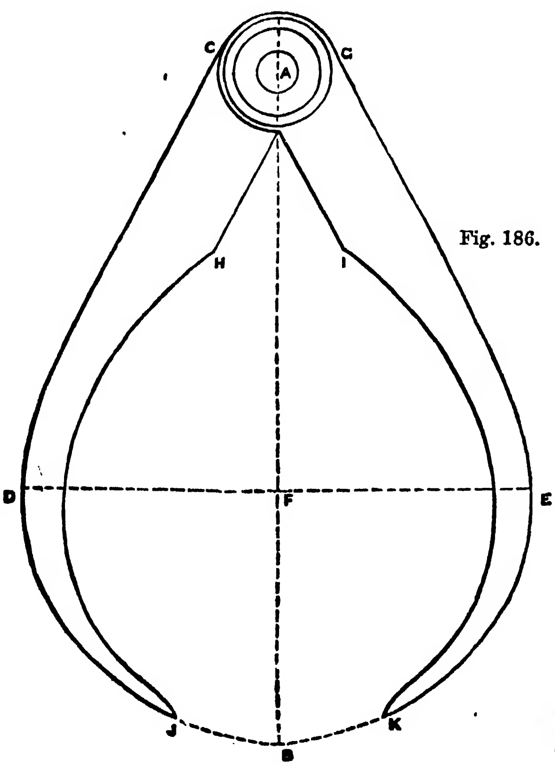


Fig. 186.

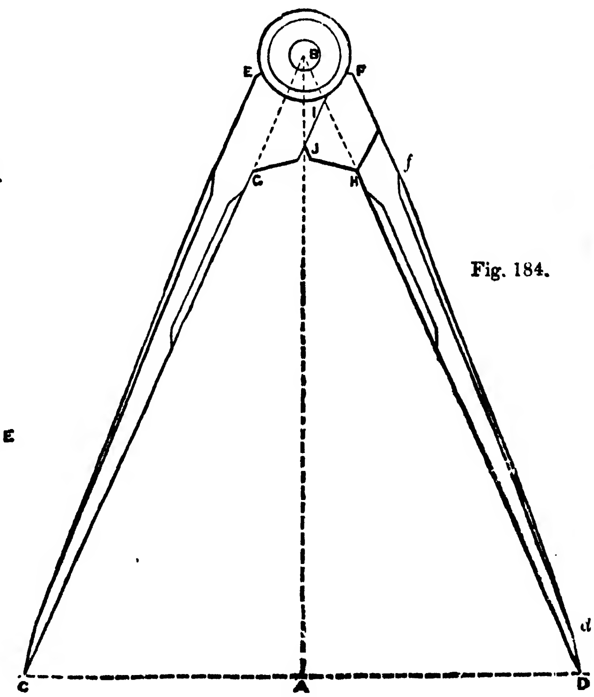


Fig. 184.

TECHNICAL EDUCATION AT HOME AND ABROAD.

VII.—EVENING TECHNICAL INSTRUCTION.

BY SIR PHILIP MAGNUS.

WHILST it is very desirable that the children of the working classes should remain at school sufficiently long to obtain a rudimentary education of a practical character which shall serve as a fitting preparation for their subsequent work, they must necessarily look to evening classes for that technical teaching which is to carry forward their early school instruction, and to supplement their workshop training. Now it frequently happens in this country that there is a great break in the boy's education at this period of his life. Where no external influence on the part of his employer is brought to bear upon the youth, he too often postpones his attendance at evening classes for some years, until he realises for himself the want of further knowledge. By this time he has unfortunately forgotten much of what he had learned at school, and consequently continues his education at a great disadvantage. In describing the system of instruction adopted in many foreign countries, we shall have to refer to evening schools, the object of which is to take up and continue the child's education from the point at which he has left it off in the primary school. These schools are known as Fortbildungschulen, or Ergänzungschulen, and are in many cases preliminary to the technical instruction which artisan students may subsequently receive. As the age at which children leave the elementary schools advances, schools of this kind, in which the subjects of primary instruction are further taught, will be less needed; but there will always be a large percentage of persons who will require supplementary teaching of this kind before they can fully profit by technical instruction.

It is of the opportunities afforded to the British workman of obtaining evening instruction in science, in art, and in technology that I propose now to speak; and it is satisfactory to find in the Report of the Commissioners of Technical Instruction the statement that "no organisation like that of the Science and Art Department and of the City and Guilds Institute exists in any continental country," and that "the absence of such organisations has been lamented by many competent persons with whom the commissioners came in contact abroad." In nearly every large town in this country, the workman and the apprentice have the opportunity of receiving sound technical instruction, embracing theoretical and practical science, art, and the applications of art and science to the special industry in which the artisan may be engaged. Although the system by which this instruction is given is now very generally known, it is desirable briefly to describe it to give completeness to this brief survey of "Technical Education at Home."

EVENING SCIENCE CLASSES.

The classes for instruction in science, examinations in which were held during the year 1886 in 1,343 different centres, are under the direction of the Science and Art Department of the Committee of Council on Education. This Department was placed under its present direction in 1856, having been originally established in 1853, soon after the First International Exhibition, from which year the commencement of technical education in this country, especially of art education as applied to industries, may be said to date. The Department receives annually from Parliament a sum of money to defray the expenses connected with its work. In 1856-57 the sum voted was £64,675, but it has increased sevenfold since then. The money so voted is expended in the payment of teachers on the results of the examination of their pupils in science and art, in prizes, in scholarships awarded to distinguished students, in assisting in the building of laboratories and the purchase of apparatus, and in the maintenance of normal schools in London and Dublin. Aid is also given to teachers and students in attendance at these schools. Examinations are held annually in twenty-five subjects, the latest addition to these subjects being Hygiene.

In 1859, when the system of making grants applicable to the whole country was first introduced, the subjects for which aid was obtainable were only six. The following is the list of subjects in which the Department now holds examinations, and in aid of the teaching of which it gives grants:—(1) Practical, Plane, and Solid Geometry; (2) Machine Construction and Drawing; (3) Building Construction; (4) Naval Architecture and Drawing; (5) Pure Mathematics; (6) Theoretical Mechanics; (7) Applied Mechanics; (8) Sound, Light, and Heat; (9) Magnetism and Electricity; (10) Inorganic Chemistry (theoretical); (10*p*) Inorganic Chemistry (practical); (11) Organic Chemistry (theoretical); (11*p*) Organic Chemistry (practical); (12) Geology; (13) Mineralogy; (14) Animal Physiology; (15) Elementary Botany; (16, 17) Biology, including Animal and Vegetable Morphology and Physiology; (18) Principles of Mining; (19) Metallurgy (theoretical); (19*p*) Metallurgy (practical); (20) Navigation; (21) Nautical Astronomy; (22) Steam; (23) Physiography; (24) Principles of Agriculture; (25) *Hygiene*. Nearly all these subjects bear directly or indirectly upon the industries of the country. Thus, while some acquaintance with mathematics, mechanics, and machine construction is necessary to the engineer, the architect and builder require a knowledge of building construction and hygiéne, the agriculturist needs to know something of biology and chemistry, and the mining engineer finds a knowledge of geology and mineralogy essential to his progress. It will be seen that in many subjects practical examinations are now held. Two of these subjects, animal physiology and physiography, though more remotely connected than any of the other subjects in the list with industrial work, attract a very large number of students. Examination in each of the above subjects consists of three stages—the elementary, the advanced, and the honours, except mathematics, which is divided into seven stages. A candidate may pass in each stage in the first or in the second class.

Payments on the results of these examinations are made to teachers at the following rates:—In the elementary and advanced stages, £2 for a first class and £1 for a second class; in the honours stage, £4 for a first class and £2 for a second class. The payments in the advanced and honours stages do not, however, appear to be sufficient to induce many of the teachers to carry on their pupils to the higher examinations. Thus in 1886, out of 60,742 successful papers at the Department's examination, only 16,663 obtained a certificate in the advanced stage, and only 791 in the honours, and of these last, 178 gained a first class. It appears to be much more to the interest of the teacher to take two classes in the elementary stage than one in the elementary and one in the advanced; and it is found that many teachers, instead of confining their attention to one or two closely-allied subjects, give instruction in several different subjects, selecting them rather on account of the facility with which their pupils can be made to pass than for their connection with one another. In this way, many science teachers succeed in making a tolerably large income. The evil of this is seen in the fact that not only are the teachers of each subject less competent than they would be if they concentrated their whole thoughts upon one set of closely-allied subjects, but the pupils are likewise induced to go up for examination in the elementary stage of a variety of different subjects, many of which have no bearing whatever upon the industries in which they are engaged. This mental dissipation serves no useful purpose, and a reform has yet to be introduced into the Department's system of payment by results by which this misuse of the encouragement afforded by the State may be avoided. With the view of aiding and encouraging the systematic study of those branches of science which are correlated, and which form the best preparation for special technical instruction, additional payments are made on account of those students who attend the full course of instruction. Thus, under certain conditions, the Department pays an additional sum of 5s. on account of each pupil who attends the full course of instruction, and passes in one of the subjects laid down for his year. The course of instruction, as laid down for day and night schools, is as follows:—*First Year:* Mathematics (subject v., first stage); Freehand Drawing (second grade art); Practical Plane Geometry (second grade art); Elementary Mechanics, including the physical property of liquids and gases (subject vi., first stage); Physics: Sound, Light, and Heat (subject viii., first stage), or Physiography (subject xxiii., first stage). *Second Year:* Chemistry, Inorganic (subject x., first stage),

with practical work; Physics: Magnetism and Electricity, frictional and voltaic (subject ix., first stage), or Physiography (subject xxiii., second stage); Mathematics (second stage and, if possible, fourth stage, subject v.); Practical Geometry (plane and solid), (subject i., first stage).

In the third year he is expected to specialise his studies in one of the following groups, taking up, for instance:—(1) Physics, Chemistry, and Metallurgy; (2) Mechanics, Steam, Machine Construction, and Drawing; (3) Mechanics, Building Construction, and Drawing; (4) Physiography, Geology, Mineralogy, and Mining.

It will be seen that the instruction aided by the Science and Art Department is only in the various branches or sub-divisions of science which underlie the explanation of the processes of arts and manufactures, but the instruction so encouraged is not specialised with a view to its application to particular industries. In this sense, it may be said to be general rather than technical, and is intended to be so. The different classes of trades are so numerous that the question of providing specific instruction adapted to the requirements of persons engaged in each particular industry is full of difficulties, and considering that the teaching of science and of art constitutes the basis, and, indeed, the greater part, of all technical education, the Department, in restricting its operations to the encouragement of teaching of this kind, does all that can be expected from the State. It will be seen, too, that the different branches of science, instruction in which is subsidised by grants, are greatly subdivided; and it is possible that the wants of artisans may be further met by an extension of this system. For instance, it has been suggested by the Commissioners on Technical Instruction that the subject of metallurgy might be divided into three sections, comprising (1) the precious metals, (2) copper, tin, lead, etc., and (3) iron and steel. Such a subdivision of the subject would doubtless be of assistance to the advanced student engaged in the working of any one of these groups of metals, but the elementary student would find a more general knowledge of the chemistry of metals essential to him in the study of metallurgical processes; and there is much to be said against the breaking up of a branch of science into separate sections in the early stages of the study of that science. Even the present arrangement of subjects is not free from such disadvantages; and objections have been raised to it on the ground that the elementary stages of the examinations do not embrace a sufficiently wide range of subjects to encourage that general and broad instruction which is needed in commencing the study of any one branch of science.

This disadvantage is a necessary and almost irremediable consequence of the system of developing the work from a common centre. If each locality were free to provide that kind of instruction best adapted to the requirements of its artisan students, it is probable that the instruction in pure science would be made to have a more direct bearing upon, and more closely to lead up to, the applications of it needed in the staple industries of the district. There is no reason why the method of scientific investigation, and the habits which the systematic study of any branch of science tend to inculcate, should not be obtainable equally from those parts of a subject which bear directly upon the industry in which the student is engaged as from other parts in which he is less interested. Whilst it is well that every student should have a general idea of the whole range of topics with which any particular science has to deal, the artisan student, who has little time at his disposal, is naturally eager to approach the consideration of those problems which have reference to the industry in which he is engaged; and there can be little doubt that if unfettered by any central authority, the teaching of chemistry, mechanics, or botany in different towns would be specialised according to the requirements of different sets of artisans, as soon as the general or introductory stage had been reached. The payment of teachers from the Imperial Exchequer renders it necessary that the instruction should be tested by the Government authorities, and no way appears to have been yet discovered of combining freedom of instruction with a guarantee of its soundness and thoroughness, except through the instrumentality of examinations, to which pupils of very different classes are equally subjected. When, however, local authorities take greater interest in the work, this difficulty will doubtless be lessened.

BUILDING CONSTRUCTION.—IX.

ARCHES (*continued*).

We now come to the square-headed window (Fig. 63), referred to in the last lesson.

Draw a perpendicular, A B, and at the point C draw a horizontal line; the point C representing the height of the top line of the sill from the ground, or some fixed horizontal line, such as a string course.

On each side of C set off half the width of the window, D and E; and at these points erect perpendiculars of indefinite height.

Now as the whole height of the jamb is to be thirty bricks, take the height of ten bricks, or any other multiple of thirty,

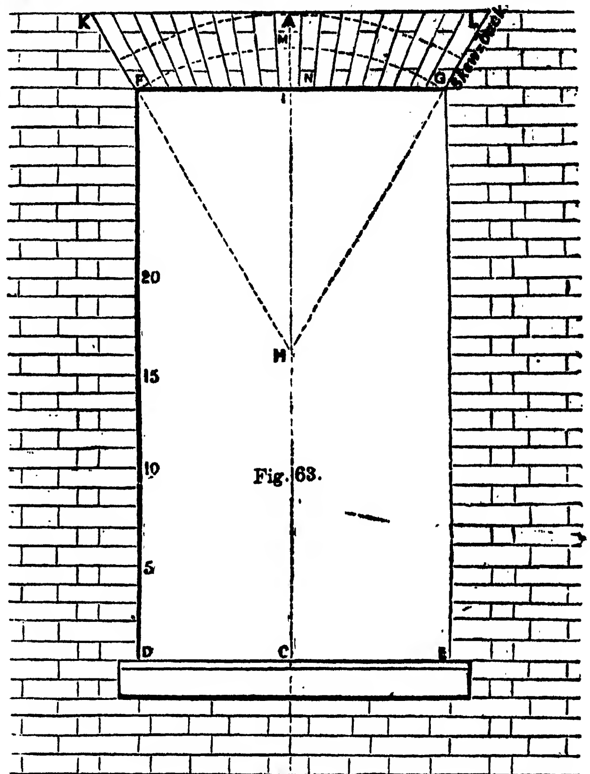


Fig. 63.

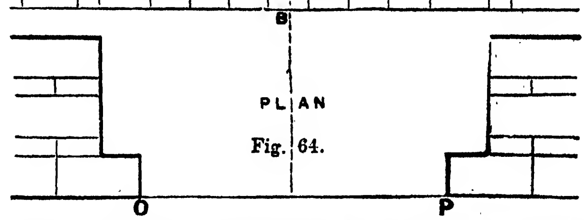


Fig. 64.

and set it off on the perpendicular D, as many times as may be required; then subdivide each of these spaces (5, 10, 15, etc.) into the proper number of bricks (this is more accurate than to set off the bricks separately); then from the highest point, draw the horizontal F G, cutting the perpendicular in I. This will complete the oblong for the window, and the line F G will form the *intrados*, or soffit, of the square arch.

Now it has already been stated that the "skew-back" usually inclines at 60°; therefore, on F G construct the equilateral triangle F G H, and produce the sides beyond F and G.

The height of a gauged arch must be some multiple of the height of one brick, on the flat with its joint—viz., three or four courses—in this instance say four; therefore, draw at that height the line K L, which will give the *extrados* of the arch.

Set off on each side of the central perpendicular on the *extrados* half the thickness of a brick, and then fill up the remaining portion of the line on each side with the widths of

bricks. From each of these points draw lines to H, which will divide the general form of the arch into a number of wedges. This will complete the straight arch. As the whole thickness of such an arch, reckoning it obliquely according to the lines of the joints of the arch bricks, and which therefore varies according to the situation of those joints, cannot be obtained from one brick, the depth is usually made up of two pieces. But the horizontal lines, M and N, are not the real joints, but false ones marked for effect; the real joints are not horizontal, but perpendicular to the centre line of the brick. The real joint soon becomes visible when time has changed the colour of the bricks.

Having done this, through the points of division in the sides draw horizontal lines, which may be carried over to

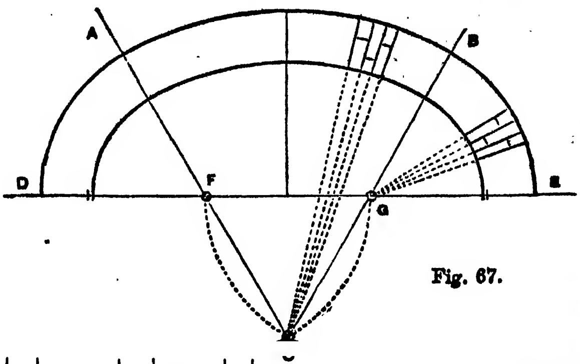


Fig. 67.

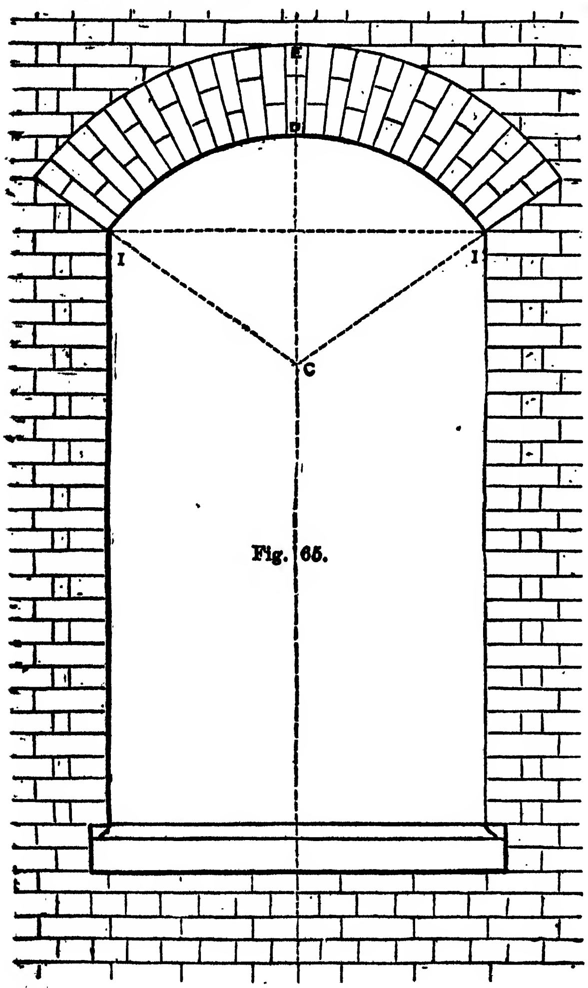


Fig. 65.

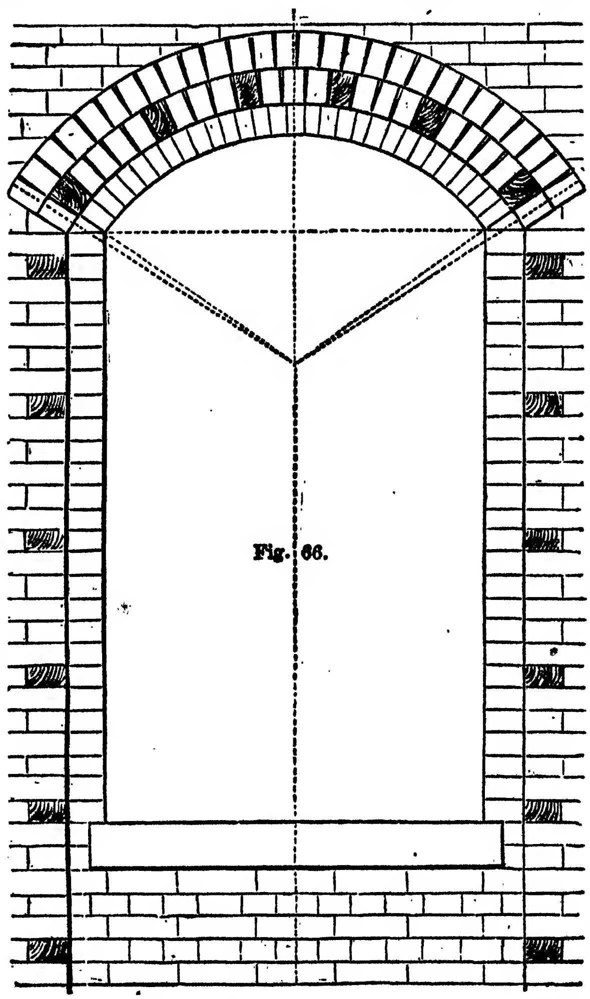


Fig. 66.

the other side; in fact, if there are several windows, or even if the courses are to be marked, they may be carried along the whole elevation, and will save all the trouble of repeating the measurement. A practical hint is, however, necessary, in order to secure accuracy in this operation. First, be very careful that your T-square is held tightly against the left edge of your board, and as you move your pencil along, let your right hand press on the blade, to prevent it rising at the middle or distant part. Where this occurs, the pencil or pen-point is liable to travel out of the required track. It is advisable to mark off with compasses on the last window, or on a line at the extreme right of the board, a few of the points, such as D 5, D 10, etc.; these will act as guide-points, and will serve to check the work. The rest of the window will be completed by marking off the whole bricks, halves, and closers, and drawing the necessary vertical lines.

It will be seen that in this window the stone sill occupies the height of two bricks. When this has been drawn, the number of courses of bricks underneath may be added according to circumstances.

Fig. 64 shows the plan of the same window. If the elevation is to be projected from a given plan, this must be finished first; and perpendiculars raised from O and P, which will give the width of the window.

Fig. 65 is a study of the front elevation of a window, the head of which is formed by a segment arch, gauged. The general form of the aperture, and the courses of bricks, the sill, etc, will all be done by the method shown in the former subject.

The centre having been fixed at C, draw radii from it touching the imposts I, I. The position of the centre will, of course, depend on the sweep or curve which is to constitute the *intrados* of the arch; for, of course, the lower the centre be placed, the longer will be the radius, and hence the flatter the arc.

Now set off D E equal to the intended height of the arch—in this case 12 inches; with C E as radius describe the *extrados*, and on it set off the width of the bricks; that is, the length of their *shortest edges*. From these points draw radii to the centre, which will give the wedge-like divisions in the arch. Divide these alternately into brick and half-brick, and complete the rest of the brickwork and sill.

Fig. 66 is the back or interior of the same window. Here it will be seen that the arch at the back is formed of *two* rings of half-a-brick each, worked as *rough* arches; the lower portion of the width of the gauged arch is thus left, and forms the revel (or reveal). This elevation shows also the positions of the wood-bricks for the attachment of the woodwork.

Segment arches are not deemed advisable in the elevations of detached or corner houses, for although they may be safe as far as the middle arches are concerned, since the thrust of each counteracts the other, and they receive mutual support from the pier, which is common to both, yet in regard to the outer arch this is not so; and as its thrust will be obliquely outwards, there will be the tendency to force the wall out of the perpendicular.

Semi-circular and elliptical arches are not, however, open to this objection, as in these the thrust is more directly downwards.

Fig. 67 is a semi-elliptical arch, using the term in an approximate sense, for it will be remembered that, strictly speaking, no portion of an ellipse is a part of a circle. The figure, however, shows the form adopted for general purposes, and the construction of such an elliptical figure will be given in a future lesson of "Practical Geometry applied to Linear Drawing."

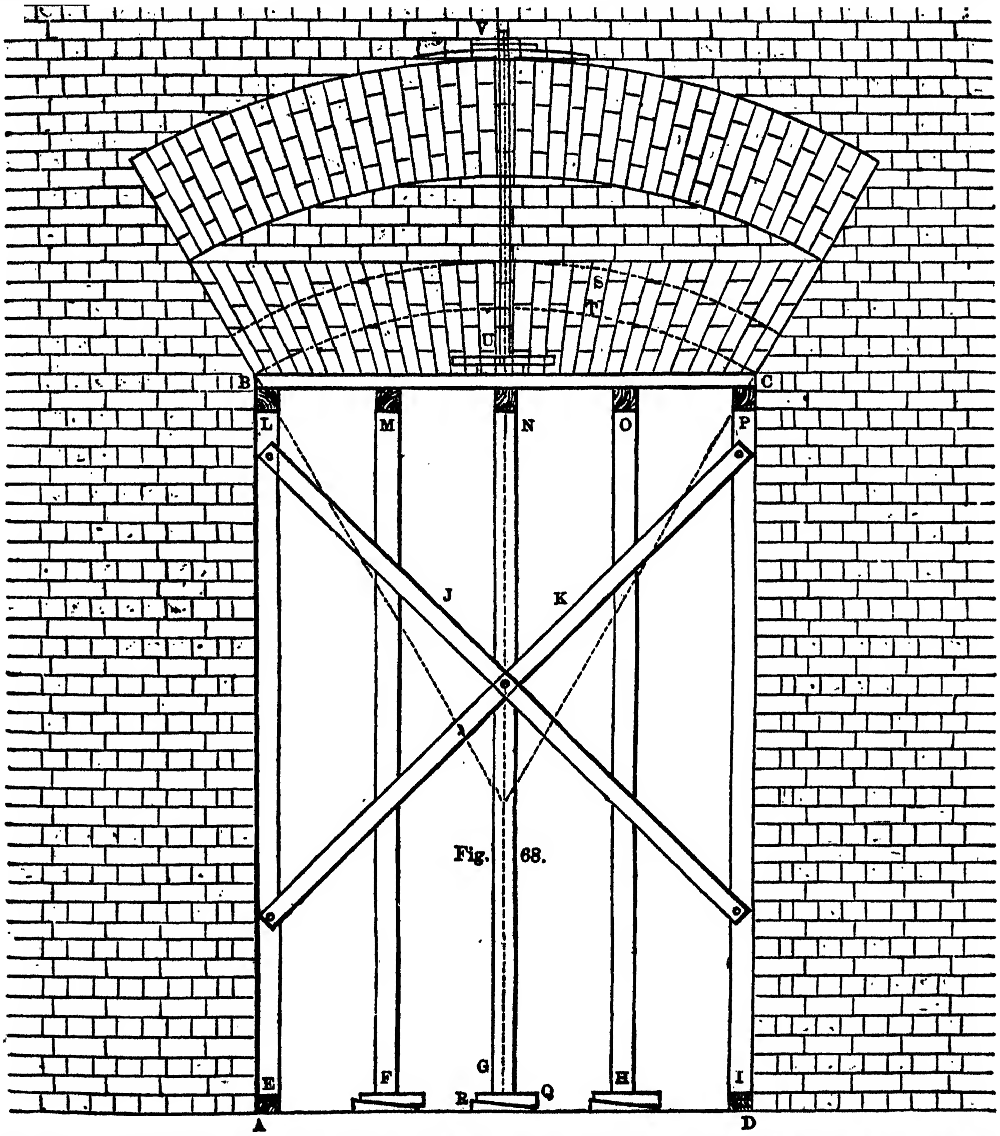


Fig. 68.

The span and rise—that is, the long and half of the short diameter—being given, construct the ellipse, and another parallel to it, struck from the same centres.

Set off on the outer curve the sizes of the bricks, and then the radii are to be drawn to the centres from which the arcs on which they are placed are struck. Thus all those between A and B will be drawn to the centre C, whilst all those between A and D and B and E will be drawn to F and G.

This subject will be further treated of when the construction of stone arches is described.

Fig. 68, taken from an excellent German example, shows the union of the straight with the segment arch.

CHEMISTRY APPLIED TO THE ARTS.—V.

BY GEORGE GLADSTONE, F.C.S.

CALICO PRINTING (*continued*).

The style of printing described in the previous lesson relates exclusively to the production of a pattern in one or more colours upon a white ground. There are, however, a variety of other effects which it is desirable to produce, that call either for a modification of the plan which has been detailed already, or for the introduction of fresh processes. These must now occupy our attention.

In many finished goods the pattern is white or tinted, while the ground is coloured. There are various ways of producing this effect. We will take first a white pattern upon blue. A resist, as it is termed, composed of acetate and sulphate of copper, thickened with gum and pipeclay, would be printed upon those portions which are to remain white, and the cloth would then be suspended in a rather moist atmosphere for a couple of days, to secure its taking thorough hold of the fabric. It may then be dyed in the indigo vat in the usual way. The portions covered by the resist are preserved from contact with the dye, and the copper salts contained in it act as a double preventive, by also withdrawing the lime from the solution of indigo which comes into contact with them, and which is necessary to its solubility, thus producing an insoluble compound on the exterior of the resist, which is subsequently easily removed by washing. Sulphate of zinc is sometimes preferred to the salts of copper; it produces the same result, by causing the oxidation of the indigo, and thus rendering it insoluble.

A yellow pattern upon a blue ground would be obtained by printing the cloth with a resist as before, and then dyeing the cloth in the indigo vat; but in this case the resist must contain nitrate of lead, as well as the copper salts and the usual thickenings; and after having been dyed the cloth must be dipped in a weak solution of bichromate of potash, when the chromium will combine with the lead in the resist, and produce the yellow colour in the pattern which is due to chromate of lead.

The vegetable colours described in the last lesson may be printed upon a cloth which is to be dyed blue by indigo; thus, a pattern in red may be produced with madder, by adopting the following procedure. The resist must contain alum and other mordants, as in dyeing Turkey red, mixed with gum and pipeclay for thickening; and the pattern be printed with it on the cloth in the usual way. After being left to age for a couple of days, the fabric has to be passed through the indigo vat, which will furnish the necessary grounding, then dunged and dyed with madder, and finally brightened with bran and soap. It will be readily seen from these instances that almost any combinations of colours may be produced in the pattern without affecting the blue grounds; just as any number of colours may be printed on a white ground, by making a proper selection of the ingredients composing the resist, the indigo having no effect upon the parts so protected, while, on the other hand, the dyes used for the pattern will not permanently fix upon any portions but those impregnated with the appropriate mordants and alterants. In dyeing the ground, however, it is not usual to immerse the goods in the indigo vat as described in Lesson II., but merely to pass them through the vat once, by carrying them over a series of rollers passing under the liquid, during the course of which they get sufficiently impregnated with the dye for this purpose.

It may be desired to produce a pattern in white, upon a ground of some other colour than indigo blue, and one that can only be fixed by a mordant. The resist will then be made of gum and pipeclay, mixed with lime-juice or other acid ingredient which shall be capable of combining with the mordant so as to produce a soluble compound. Such a resist will effectually protect those portions of the cloth printed with it from the iron and aluminous mordants used in dyeing with madder and other vegetable colours. Tinted figures may also be produced with such groundings, by including the salts of tin in the resist. In these cases the usual processes of mordanting, ageing, dunging, and clearing will have to be gone through after the reserves have been printed with the resist.

We must now consider a totally different plan of attaining the same result, and one which is adopted in many large works. Instead of preserving the pattern from the influence of the dye by means of resists, it consists in depriving portions of the cloth of the colour they possess, in order to produce a pattern. This is technically called *discharging*. It is the very opposite of the preceding operation. For this purpose the usual bleaching agents are in requisition, but they have to be differently applied, as their action has to be limited to those spots which are to constitute the pattern. The ordinary process of bleaching by chlorine is, comparatively speaking, a slow one, but it can be greatly expedited by the addition of an acid to set free the chlorine contained in the bleaching-powder. A piece of goods uniformly dyed with madder in the usual way can have a pattern printed upon it containing an acid discharger, and on immersing it afterwards in a solution of chloride of lime, the parts printed with the discharger will be bleached by the chlorine set free by the acid, before the liquor will have exercised any appreciable effect upon the portions not so printed. The operation is, of course, stopped the moment that the pattern has been properly developed, which ordinarily will not occupy more than two or three minutes, on which account it is found most convenient merely to draw the cloth through the liquid by passing it between squeezing rollers. After passing the second pair of these it goes into the dash-wheel, in order to be thoroughly washed.

Another plan of applying the bleaching liquor to certain portions of the surface is largely adopted in printing handkerchiefs in imitation of the Indian bandanas, in which the aid of powerful machinery is brought into requisition. Hydraulic presses are employed, which convey motion to two plates, an upper and an under, which are perforated with holes exactly corresponding with the spots which are to be bleached. Upon the lower plate a number of pieces of Turkey red cloth are laid very evenly, and it is then raised by the hydraulic pump until it presses against the upper plate with the force of about 300 tons. The bleaching liquor is then poured into the interstices in the upper plate which form the pattern, and passing through the cloth and out by the corresponding spaces in the lower plate, it carries with it all the colour, while the rest of the cloth is preserved from any action of the chlorine by the extreme pressure put upon it. The action of the bleaching liquor is accelerated by mixing with it some sulphuric acid, and if a strong solution is used the chlorine is forced through by artificial pressure. As soon as this process is accomplished, pure water is passed through in the same manner, in order to wash away the chlorine. If, instead of a white pattern, one of some other colour be desired, it can be communicated without removing the goods from the press; but when the whites are to be filled up with some parti-coloured device, the hand-block is generally used for the purpose.

When a discharge is to be produced upon an article dyed with indigo, chromic acid is used instead of chlorine. The plan adopted is as follows:—The surface of the blue cloth is padded with a solution of bichromate of potash, by passing it under a roller the lower portion of which is immersed in the liquid, then between the drying rollers to squeeze out the excess, and afterwards through a hot flue; it is then printed with a discharger ordinarily made of oxalic and sulphuric acids thickened with starch, and immediately washed in water containing a little chalk. The acids contained in the discharger combine with the potash, leaving the chromic acid free to act upon the indigo, and so depriving the latter immediately of its colour. The cloth is then thoroughly washed in the dash-wheel. If some of the salts of lead be added to the discharger, a yellow instead of a white pattern will be the result.

In cases where dyes are employed which require the presence of mordants or alterants, the dischargers are used before dyeing instead of afterwards. The object then is to annul the effect of the mordant, so that at the subsequent process of dyeing the colouring matter shall not take permanent hold of those parts which are to remain white. The mordants generally used for vegetable dyes—alum and the salts of iron—are best neutralised by lime-juice, tartaric and oxalic acids, thickened in the usual manner.

Mineral colours are usually discharged in the same way as the mordants above described, and by means of the same acids, the result being that the salt of the metal enters into combination with the acid, forming a compound which in some instances is colourless, and in others can be removed by washing; in either case the desired effect is equally attained. If Prussian blue is the colouring material, the cloth must be first printed

with a paste made with caustic alkali, and then immersed in oxalic acid. The process already described in dyeing with this colour will then be reversed on these portions of the fabric, and the resulting compounds will prove removable by washing. Sometimes, however, it is the object of the dyer to combine with the discharger other substances which shall act as mordants for colours to be subsequently applied; thus the protochloride of tin may be used to decompose a brown produced by manganese, and at the same time form a mordant for such dye-stuffs as quercitron or logwood; and further combinations may be made, each several discharger being applied in succession by a different cylinder, so as to produce at the subsequent dyeing so many different shades or colours in the pattern.

There is again another process for printing a pattern in various shades of blue, which is a modification of the ordinary mode of dyeing with indigo. It is only applicable to this particular dye, but is, nevertheless, of sufficient importance to warrant a detailed description. Instead of converting the blue indigo of commerce into the white soluble indigo in the vat, and then working the whole piece in the liquid, which would produce a uniform depth of colour throughout, the indigo is printed on the material in its blue state, and is afterwards dissolved. By this means a permanent figure in blue can be produced upon a white ground, and, by varying the strength of the composition communicated to it by the cylinder or block, any required shade or any number of shades can be obtained. The composition used for this purpose usually contains about equal weights of indigo and sulphate of iron, finely ground, and mixed up into a paste with a varying quantity of gum-water or starch, according to the depth of colour required. Sometimes the acetate of iron is substituted for the sulphate. As many pastes of different strengths as may be wished are printed from successive cylinders upon the white cloth, and it is then hung up to dry for about a couple of days. Three vats are then prepared, the first containing an aqueous solution of lime, the second of sulphate of iron, and the third of caustic soda. Into these vats the cloth is dipped in the following order—into the lime and iron twice alternately, then into the soda, next into the iron and lime twice alternately, then again into the iron, and lastly into the soda. Each dipping should occupy ten minutes, with an interval between each of five minutes, to allow for the solution draining off. The oxide of iron which will be deposited on the goods during these immersions is got rid of by passing them through a bath of dilute sulphuric acid, after which they are well washed in pure water. The materials employed will be seen to be nearly the same as those used for dyeing in the indigo vat, and the result is due to the same chemical action. At each immersion in the lime-vat a certain portion of the sulphate or acetate of iron is decomposed, and an equivalent quantity of the indigo rendered soluble, which then enters into the fabric, and becomes oxidised again while the cloth is hanging up to drain, so that by the time it has undergone the series of dippings prescribed a sufficient depth of colour will have been attained. This style is generally known as "China blue printing."

Vegetable dyes used with the salts of tin, commonly called "spirit colours," produce brilliant patterns, but unfortunately they are not fast. Many colours may, however, be printed with a mordant, and then fixed by the action of steam, so as to produce an effective and permanent design. For this purpose a steam-chest has to be provided, in the upper part of which the goods are suspended for half to three-quarters of an hour, while the steam is let in by a pipe from below, care being taken not to let the steam condense upon them, or the dyes would be apt to run. In some dye-works high-pressure steam is applied, when the duration of the steaming is reduced to one-half the time. A good red is obtained by this process with Brazil or sapan-wood printed with an aluminous mordant, and a very brilliant colour with cochineal combined with chloride of tin and oxalic acid. Yellow berries are generally used for the colour indicated by their name, which may be employed either alone or with a tin mordant, the latter communicating to them an additional brilliance. The ferrocyanide of potassium is always used when a steam blue is required. Black can be produced by this means; an extract of logwood and galls combined with an iron mordant producing the reaction which has already been described in the lesson on dyeing.

The intelligent reader will not fail to observe that the various processes described in this and the preceding article are capable of being combined, and some of the best effects are realised by a combination of one or more of them. In order to avoid confusion, the printing of cotton goods has been exclusively treated; woollens and mixed fabrics have also to be dealt with in practice, but these are of so much less importance that the reader must be left to apply to them such modifications as will be suggested by a consideration of the principles which have already been laid down when speaking of the dyeing of these classes of goods.

PROJECTION.—XI.

ISOMETRICAL PROJECTION.*

In all the previous constructions, it will have been observed that the projections have been obtained by the union of *plans* and *elevations*.

Isometrical Projection enables the draughtsman to work out views of buildings, etc., without these separate drawings, but still embodying both. This most useful system may be called the perspective of the workshop, as by its means we are enabled, not only to show in one drawing a view of the complete object, but all the lines of the projection may be measured by a uniform scale; and hence the name, *isometrical*, derived from two Greek words meaning "equal measures."

In this respect it differs from perspective, in which the sizes of all objects and lines diminish as they recede into the distance, according to distinct optical laws; and it differs also from orthographic projection (which has formed the subject of our study hitherto), as in that branch of science the lengths of the lines are altered according to the angle at which the object may be placed. The whole system of isometrical projection is based on a cube resting on one of its solid angles, whilst its base is raised until the one solid diagonal—that is, the diagonal which connects the one angle of the top to the opposite angle of the bottom—is parallel to the horizontal plane. Then, if the cube be rotated on the angle on which it rests until the diagonal is at right angles to the vertical plane, the projection of the cube will be a regular hexagon. This will be clearly understood on referring to the following figures.

THE ISOMETRICAL PROJECTION OF A CUBE.

Fig. 115 is the plan and Fig. 116 is the elevation of a cube, when raised on the solid angle *a*, so that the solid diagonal, A *b*, is horizontal, and thus when rotated on *a*, until A B is at right angles to the vertical plane, as in Fig. 117, the point *b* is hidden by the point A, and the projection will be seen to be a *regular hexagon*.

Now we know that when a regular hexagon stands on one angle, so that a line drawn from that angle to the centre may be quite upright, the two sides adjacent will be at 30° to the line on which the figure stands; and this knowledge enables us to draw the isometrical projection of a cube without plan or elevation, but by means of the set-square of 30°, 60°, and 90°, by simply placing it with the long side of the right angle against the T-square (see Fig. 118), and having drawn one line of the hexagon, reversing the set-square and drawing the other, then either moving the square along until its short edge is at the point of meeting of the two previously drawn lines, or turning it so that the short edge rests on the set-square, and thus drawing the vertical line. These three lines are then to be made equal, and the upper lines of the hexagon may be drawn, by again placing the set-square in the first and second position when the T-square is moved higher up on the board. All the lines forming the projection of the cube will thus be seen to be equal, but they will *not* be the real size which they would be in the plan or elevation, but will all of them bear the same proportion to the original measurement, and may therefore be measured by a uniform scale throughout.

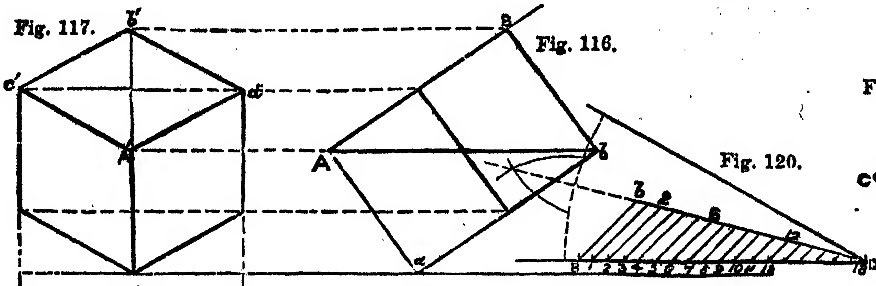
To understand the construction of the isometrical scale, observe that the square, A B C D (Fig. 115), is represented in the projection (Fig. 119) by the lozenge, A′ C *b* D, and that all the other sides, which we know to be squares equal to A B C D, are represented by lozenges similar and equal to A′ C *b* D. In Fig. 119, therefore, this lozenge is placed within the square, and it will then be seen that the side D B of the square is at 45° to

* Invented by Professor Farish, of Cambridge, about 1820.

Fig. 117.

Fig. 116.

Fig. 120.



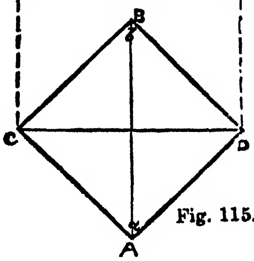
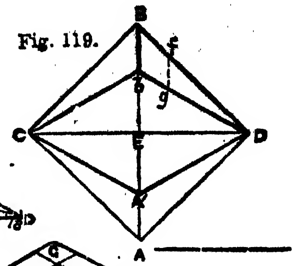


Fig. 115.

Fig. 119.



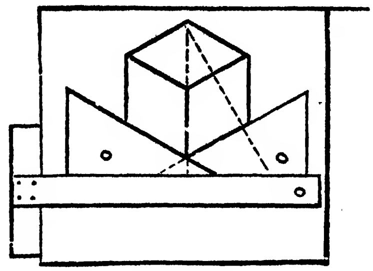


Fig. 118.

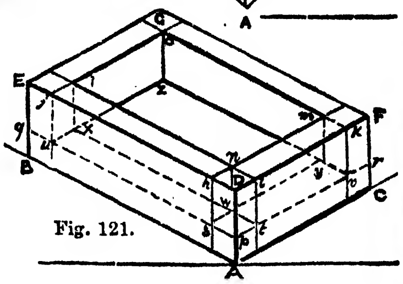


Fig. 121.

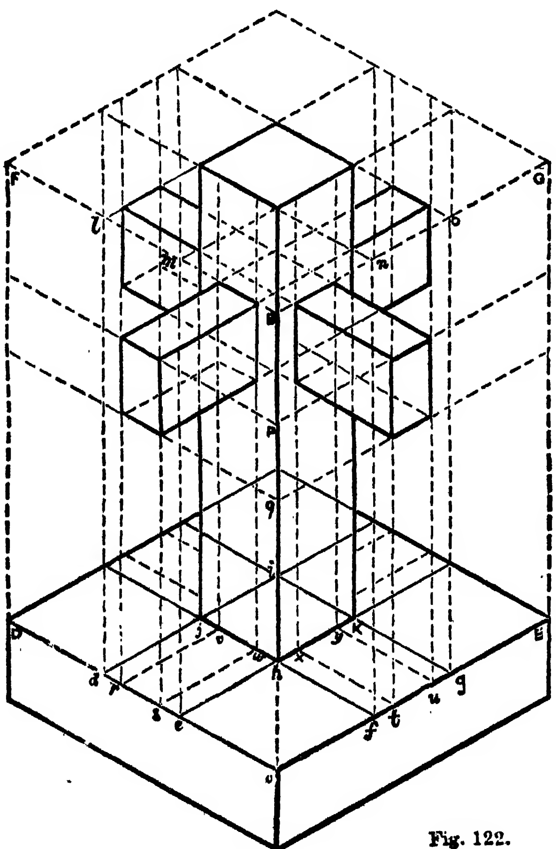
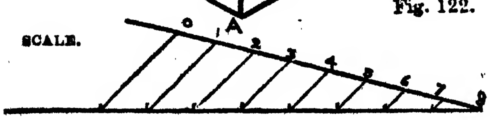


Fig. 122.

SCALE.



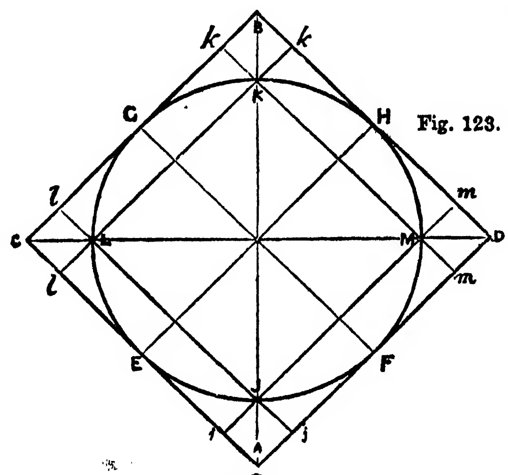


Fig. 123.

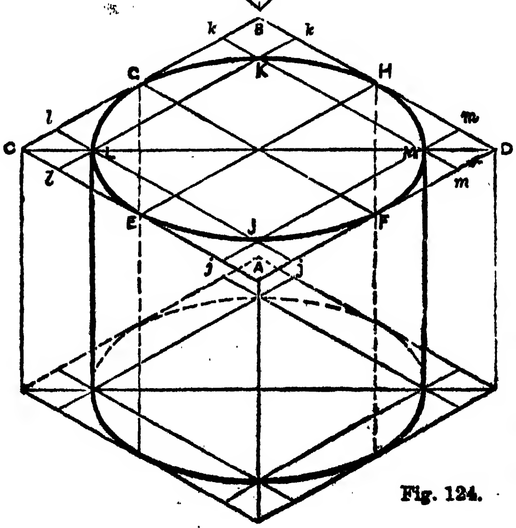


Fig. 124.

D F, whilst the side of the lozenge, D *b*, is at 30° to D E. The difference, then, between the triangle D E *b* and the triangle D E B, is the triangle D *b* B, the angle *b* D B being 15°, and D B *b* being 45°.

It will therefore be plain that if a side of a cube be given, and we are required to find the side of the hexagon which should form the isometric projection of the cube, we need only take the given length as the base of a triangle, as D B. Construct an angle of 15° at one end (D) and of 45° at the other (B). Then the side D *b* of such triangle will be the required length of the side of the hexagon, and any divisions or parts marked on B D, as B *f*, may be transferred to *b* D, by drawing a line from *f*, parallel to B *b*, cutting *b* D in *g*; then *b g* will have the same proportion to B D that B *f* has to B D.

TO CONSTRUCT AN ISOMETRICAL SCALE.

Now let it be required to construct an isometrical scale, so that the object delineated may be one-twelfth of the real size. It will, of course, be understood that this scale is *one inch* to the foot, as an inch is one-twelfth of a foot; and further, that if this inch be divided into twelve equal parts, each of the twelfths will represent the *inches* of the real measurement; that is, they will bear the same relation to an inch that an inch does to a foot—viz., one-twelfth; and, therefore, as in the proposed scale an *inch* represents a *foot*, necessarily a twelfth of an inch represents an inch. The object to be projected is a box, 1′ 6″ long, 1′ 0″ wide, and 6″ high; the sides and bottom being 2″ thick.*

Draw the line B D (Fig. 120) an inch and a half long, representing the real length of the box—viz., a *foot* and a *half*, and mark on this the twelfths of inches, which are to *represent inches* on the scale. Draw at D a line at 15° to D B (which is most accurately done by drawing a line with your 30° set-square, and bisecting the angle). Draw at B a line at 45° to B D, cutting the line drawn from D in *b*; then the triangle B *b* D in Fig. 120 will be similar to the triangle D *b* B in Fig. 119, and therefore D *b* in Fig. 120 will have the same proportion to B D that the lines similarly lettered in Fig. 119 have to each other. From the points 1, 2, 3, 4, etc., in B D draw lines parallel to B *b*, and these will divide *b* D proportionately to B D, and the divisions will thus, on the isometrical drawing, represent inches, and the line D *b* is an isometrical scale of $\frac{1}{12}$.

TO PROJECT A BOX ISOMETRICALLY.

We can now attempt the object, Fig. 121. By means of the set-square of 30°, draw the lines A B and A C; make A B 1′ 6″ long by the isometrical scale (the *line* D *b*), and make A C 1′ long. At A B and C draw perpendiculars.

Make A D 6″ high, and from D draw lines parallel to A B and A C, and cutting the perpendiculars B and C in E and F.

From E and F draw lines parallel to D F and D E, meeting in G, and this will complete the object as far as the mere block is concerned; and as a rule, it is advisable to project the general block view before attempting the detail.

From D, E, and F, mark off 2″ by scale—viz., *h*, *i*, *j*, *k*, and from these draw lines parallel to D E, D F, which, intersecting in *l*, *m*, *n*, *o*, will give the inner edge of the sides of the box, which, it will be remembered, are 2″ thick.

The bottom of the box is also 2″ thick, therefore on the perpendicular A set off A *p*, and draw *p q* and *p r* parallel to A B and A C.

From *h*, *i*, *j*, *k* draw perpendiculars to cut these lines in *s*, *t*, *u*, *v*, and from these points draw lines parallel to the sides of the box, cutting perpendiculars drawn from *l*, *m*, *n*, *o* in *w*, *x*, *y*, *z*, which will show the junction of the inner sides of the walls and the bottom, and will complete the projection.

TO PROJECT A FOUR-ARMED CROSS.

Fig. 122 shows the isometrical projection of a four-armed cross standing on a square pedestal. Scale, ¼ of an inch to the foot; side of pedestal, 8 feet; height of ditto, 2 feet; complete height of cross, 14 feet.

The pedestal having been projected in a manner precisely similar to that by which the box (Fig. 121) was drawn, carry up the perpendiculars from the angles; make the perpendicular A B 14 feet high, and by drawing lines from E parallel to the sides of the base, complete the top of a block which would contain the entire object; for, as the complete height of the cross is 14 feet, the top of the upright would be in the top of the block; and as the arms are 8 feet long from end to end, their extremities would be in the sides of the block, which may thus represent a glass case exactly containing the cross.

The thickness of the central upright is 2′ 0″; and as the width of the side of the pedestal is 8′ 0″, it follows that if 3′ 0″ be marked off from C to *e*, from D to *d*, from C to *f*, and from E to *g*, the spaces *d e* and *f g* will each be 2′ 0″.

From *d*, *e* and *f*, *g* draw lines parallel to the sides of the pedestal, which, crossing, will give the lozenge *h j i k*, which is the plan of the central upright. From *d*, *e*, *f*, *g* draw perpendiculars to touch the edges of the top of the solid block, B F and B G in *l*, *m*, *n*, *o*, and lines drawn from these points parallel to the sides will give the top of the central upright. On the front perpendicular A mark off *q* at 9′ 0″, and P at 11′ 0″ from the bottom, and from these points draw lines parallel to the sides C D and C E. These will give the heights of the top and bottom edges of the arms. But the arms are not so thick as the central upright, being only 1′ 0″; therefore between *d* and *e*, and *f* and *g*, mark off half a foot from each of the points. This will leave the spaces *r s* and *t u* each 1′ 0″ wide. From these draw perpendiculars, which, cutting the lines drawn from *p* and *q*, will give the ends of the arms; then draw lines parallel to the sides of the pedestal, cutting *h j* and *h k* in *v*, *w* and *x*, *y*, and from these points draw perpendiculars. From the angles of the ends of the arms draw lines parallel to the sides of the pedestal, cutting these perpendiculars, and these will complete the two arms which are turned towards the front. By producing these lines as shown in the diagram, the portions visible of the opposite arms may be drawn. All further detail will, it is hoped, be rendered clear by reference to the figure.

THE ISOMETRIC CIRCLE.

Projection does not deal with curves as such, but it becomes necessary to find points in rectilineal figures through which the curves pass, then to project the rectilineal figure, and trace the curve through the points so obtained. Thus for isometrical purposes (as in radial perspective) the circle is enclosed in a square (Fig. 123).

Having drawn the circle, describe around it the square A B C D. Draw the diagonals, and also the two diameters, at right angles to each other, meeting the sides of the square in the tangent points E, F, G, H.

The circle not only touches at these four points, but cuts through the diagonals in the points J, K, L, M. Draw lines through each of these points, cutting the sides of the square in *j*, *k*, *l*, *m*.

Proceeding now to project the circle thus prepared, draw the diagonal C D in Fig. 124 equal to C D in Fig. 123. From C and D draw lines at 30° to C D, intersecting in A and B. This will be the isometrical representation of the enclosing square.

The points E, F, G, H and *j*, *k*, *l*, *m* are obtained by marking from A the distances A *j*, *j* E, E *l*, and A *j*, *j* F, and F *m*, and drawing lines from these points parallel to the sides of the figure. The intersections J, K, L, M will thus be obtained through which the ellipse, which is the isometrical projection of the circle, is to be drawn. The study may be carried on to the projection of a cylinder, by repeating the operation for the bottom, and joining the intersections by perpendiculars.

The limits of these papers necessarily preclude further illustrations of this branch of projection. Various objects will, however, be delineated on this simple system in the lessons in Technical Drawing devoted to Architectural and Engineering Drawing.

ANIMAL COMMERCIAL PRODUCTS.—XI.

PRODUCTS OF THE CLASS PISCES (*continued*).

In our last lesson it was stated that Cuvier divided the class Pisces into two sub-classes—

1. *Pisces ossei*, or bony fishes.
2. *Pisces cartilaginei*, or cartilaginous fishes.

The first sub-class of osseous fishes is arranged according to the character of the organs of locomotion into—

Acanthopterygii (Greek *akantha*, a spine, and *pterygion*, a fin), or spiny-finned fishes. Examples: perch, mackerel, and mullet.

* The student is reminded that one dash (′) over a figure means *feet*, and two dashes (″) *inches*; thus 1′ 6″ is one foot six inches.

Malacopterygii (Greek *malakos*, soft, and *pterygion*, a fin), or soft-finned fishes. Examples: herring, salmon, carp, and trout.

Fish constitutes an important article of commerce, furnishing us with immense quantities of oil and an abundance of food. Great Britain possesses a coast-line of 3,000 miles in extent, while that of Ireland is above 1,000 miles, and the greater part of the shores of both islands abounds in those species of fish which exist in the largest numbers and yield the most acceptable and nutritious food. Hence a hardy and adventurous race of fishermen has arisen, well supplied with vessels beautifully built, and with materials of the best description. We shall notice only the fisheries commercially most valuable.

Herring (*Clupea harengus*).—This fish appears in vast shoals upon our coasts from July to November, when it forsakes the deeper portions of the sea where it habitually dwells, and comes into the shallow shore water for the purpose of spawning. These shoals, animated by a common impulse, are so enormous that the sea for miles round shines with a silvery lustre from their glittering scales. It is certainly a wise and beneficent law which thus impels certain fish to approach the shore to deposit their ova; for whilst the best means are being taken for the continuance of the species, there is brought within the reach of man an abundant supply of nutritious food, which would otherwise be lost in the depths of the ocean.

The British and Irish herring fisheries are principally carried on off Galway, Mayo, in the estuary of the Shannon, and Waterford, in Ireland; at Cardigan Bay and Swansea, in Wales; at Yarmouth, Lowestoft, Hastings, and Folkestone, in England; and on the coasts of Caithness, Sutherland, Ross, Aberdeen, Banff, Moray, and Berwickshire in Scotland. Some idea of the extent of this fishery may be inferred from the figures given by the Duke of Edinburgh at the Fisheries Exhibition (1883): "The quantity of herrings taken in a year by British fishing vessels probably approaches some 300,000 tons, at an average of 5,500 to a ton weight; this represents in round numbers 1,650,000,000 fish." In Norway about 600,000 tons of these fish are annually taken and salted. Sweden, Denmark, Holland, and France are also largely engaged in this business.

The *Pilchard* (*Clupea pilchardus*) closely resembles the herring. This fish is very abundant on the coasts of Cornwall during the spawning season in July. Like the herring, it is taken with the net at night. The average annual produce of the Cornish pilchard fisheries is estimated at 21,000 hogsheads, each annually containing 2,500 fish, thus making the total number captured 52,500,000. About 10,000 persons, young and old, are employed, and the capital invested in boats, nets, and cellars for curing, is estimated at £441,215.

The *Sprat* (*Clupea sprattus*), although smaller than the herring, is also very abundant, and furnishes an acceptable supply of cheap and agreeable food. It is caught during the winter months on the coasts of Kent, Essex, and Suffolk, and in such vast quantities as to give rise to the Stow Boat fisheries round the Thames estuary, where they are taken for manure, many thousand tons being sold to the farmers at from 6d. to 8d. per bushel for this purpose. Forty bushels of sprats serve for an acre of land.

Whitebait (*Clupea alba*).—Every one has doubtless heard of the whitebait dinner—or fish dinner, at which whitebait is the chief dish—for so many years held at Greenwich by the members of the British Cabinet, and the Lord Mayor and aldermen of London. This little fish, so much prized for its delicious flavour, was formerly regarded as the fry of the shad, while other naturalists maintain that it is quite a distinct species. Günther, an authority of high repute, has pronounced that whitebait is the fry of the sprat. It has never been found with matured ova, and therefore does not ascend rivers for the purpose of spawning.

Sardine (*Clupea sardina*) and *Anchovy* (*Engraulis encrasicolus*), both closely allied to the herring, replace that fish in the Mediterranean. The former is taken in great abundance off the shores of Sardinia and Brittany, and packed in small metallic boxes, and is much esteemed as a breakfast relish. The latter, a small silvery fish four or five inches in length, is found on the coasts of France and Portugal. The head and entrails having been removed, it is salted and packed in barrels, and forms the well-known condiment, anchovy sauce. "More than 4,000 boats and a population of nearly 25,000 fishermen find employment in these fisheries during the season" ("Fisheries of the World," by F. Whymper).

Mackerel (*Scomber scombrus*).—This well-known and beautiful fish, so valuable as an article of food, is found in abundance on the south and south-east shores of England. Out of the water it soon dies, and becomes quickly tainted. Those caught in the months of May and June are preferred. They will bite at almost any bait, and quantities are taken by hook and line. A strip of red leather, a piece of scarlet cloth, or a slice of mackerel is a successful lure. "Canada is beginning to realise the value of this fishery, for over 74,900 barrels of pickled mackerel and 394,489 cans of the same fish were exported by her in 1882."*

Salmon (*Salmo salar*).—This is a soft-finned fish, the body being adorned with spots, and brilliantly coloured, and covered with cycloid scales. The species pass by almost insensible gradations into the clupeoid or herring family. Like the herring they inhabit the sea, and not only approach the land, but ascend the rivers nearly to their sources in order to deposit spawn. For this object the salmon reaches the small streams near the sources of rivers, displaying an amount of perseverance and activity in getting there which is astonishing. Cataracts and weirs ten and twelve feet in height are cleared at a single leap, and should the fish be foiled the first time, it tries again until successful.

After spawning salmon are totally unfit for food. They descend the rivers to the sea with the floods, with which winter usually closes, where they soon recover their condition, and return ample in size and rich in human nourishment, exposing themselves in narrow streams as if Nature intended them as a special boon to man. Such salmon as are taken in estuaries or rivers are, of course, the property of those to whom the estuaries and rivers belong; but latterly considerable quantities have been caught in bays and in the open sea, where the fishing is free. The London markets are principally supplied with salmon sent up from the Tweed, Tay, Don, and Dee, and from Norway, preserved fresh by being packed in ice. The fishing is usually carried on in summer, and when the take is greater than can be conveniently sent off fresh, the residue are salted, pickled, or dried for winter consumption at home, or for foreign markets. Of late years there has been a decrease of salmon in the English and Scotch rivers, the result of poaching and over-fishing. Legislation has done something to remedy the evil. Pecuniary penalties are inflicted on poachers and trespassers; and in Scotland the rivers are shut up, on the Tweed from September 14th to February 15th, and north of the Tweed from September 14th to February 1st.

Cod (*Morrhua vulgaris*).—This valuable fish is spread throughout the seas of Europe, from Iceland to Gibraltar, and abounds on the eastern coast of North America from 40° to 60° N. lat., particularly around Newfoundland. It spawns in British waters about February, and is in the best condition as food from the end of October to Christmas. It is amazingly prolific, 9,384,000 ova or eggs having been counted by Leuwenhoeck in the roe of one female. As the cod frequents deep water, it can only be taken by long deep sea lines, hooks being fastened at regular distances along their entire length. It is usual to fish for cod in water from twenty-five to forty fathoms in depth, with a hook and line. Cod is voracious, and easily taken with a variety of baits.

The British cod fishery is carried on in a number of places contiguous to the shores of our islands. The most productive home fisheries are those off the coasts of Norfolk, Suffolk, Essex, Lincolnshire, and the Orkney, Shetland, and other islands. The London market is supplied chiefly from the Norfolk and Lincolnshire fisheries. Fresh cod are usually kept alive in welled smacks, and are in this manner brought in good condition from the most distant points of our coasts. The well is capable of holding about fifty score, and receives its water directly from the sea, through perforations in the bottom of the vessel. These vessels are either anchored in a tide-way, or one of the sails is kept set, so as to produce a constant heaving motion, and, in consequence, a perpetual change in the waters of the well. The smacks never go farther up the Thames than Gravesend, as the fresh water intermingles with the salt above that point, and proves destructive to the fish.

* See "Fisheries of the World" (Cassell & Co., Limited).

WEAPONS OF WAR.—V.

BY AN OFFICER OF THE ROYAL ARTILLERY.

BREECH-LOADING SMALL ARMS (*continued*).

We have already spoken at some length of the introduction of the Snider-Enfield rifle; it is necessary, however, to say something more on the subject of the cartridge for this arm, because it is now recognised that the cartridge really constitutes the soul of any system of breech-loading small arms. The cartridge has been compared to the hinge upon which the system turns; once select a good cartridge, and the difficulty of finding a good rifle is more than half solved. The foundation of a good system is laid, at any rate; and it becomes very much a matter of individual preference whether the cartridge shall be used with this or that breech-action. At this moment there are so many good rifles before the public that the difficulty consists rather in deciding which is the best than in deciding whether any one of them will do.

All these systems have a point of contact in the cartridge. They do not all fire identically the same cartridge, although they could, of course, be made to do so; but they all fire a metallic cartridge—a cartridge which forms a gas-check at the breech, and which has to be withdrawn after firing, and either thrown away or re-filled. There are two great classes of cartridges—those which belong to the class above described, *cartouches obturatrices*, as the French call them, for the reason that they "obturate," or seal the breech at the moment of explosion; secondly, cartridges which are intended to be consumed by the explosion, the arm itself or some portion of the breech mechanism furnishing the gas-check. The English "Boxer" service cartridge, the solid metal cartridge, the stout pasteboard sporting cartridges, are all types of the first class; the Chassepot and needle-gun cartridges are types of the second class. The objections to the second class of cartridges are not inconsiderable. In the first place, the gas escape being taken by the breech of the gun, continued firing tends to make that check less effectual. In the needle-gun, for example, where there is only a mechanical fit of one metal upon another, the "spitting" of fire at the breech is inconveniently great. The same thing occurred in our own cavalry "Sharp" breech-loaders. In the Chassepot the spitting is prevented by an india-rubber ring or washer, which, however, is liable to become injured by use, or hard with frost, or rotten with heat, and which then, of course, fails to fulfil its object. Indeed, we have been informed on credible authority that this defect exhibited itself to a very considerable and inconvenient extent during the Franco-German war (1870-1). Again, although cartridges of this class are supposed to be consumed by the discharge, it is a fact that they frequently are not altogether consumed—*débris* collects and fouls the chamber of the gun, and loading, after a time, becomes difficult. Again, if made very thin, these cartridges are liable to be exploded *en masse* by the accidental ignition of one or two cartridges in their midst.

The list of objections could be largely extended; but the three which we have named will suffice to show that the English military authorities are not without reason in having set their faces against the "consuming" cartridges, and in having adopted the *cartouche obturatrice* for use with our military rifles. For with an obturating cartridge you renew your gas-check each time of firing; you have a cartridge which cannot be exploded by the adjacent explosion of another cartridge; you have a cartridge far more capable, because stronger, of resisting rough usage, transport, and damp; you have a cartridge which, if a miss-fire occurs, can be withdrawn without the use of the ramrod, by simply applying the ordinary extractor; you have a cartridge, also, which is less liable to miss fire, for the reason that its position in the chamber is always determined accurately by means of the projecting metallic base; while with the paper cartridge the position in the chamber varies according to the exact size of the cartridge and of the chamber, the former being, of course, variable, according as the cartridges become deformed in handling and transport.

All these advantages belong to the class of cartridges of which the English service cartridge—the invention of General Boxer, R.A.—forms one of the best known and most successful types. In this the maximum of strength is obtained with the minimum of metal. A pasteboard cartridge is inadmissible for military purposes, because it is liable to swell with damp, and is more or less susceptible to injury in other ways. We are, therefore—having narrowed our selection down to the obturating non-consuming class of cartridges, and having eliminated from this class the pasteboard cartridge—left to choose between a cartridge on the Boxer or coil system, and one on the solid metal system. The latter is much more costly than the former, more metal being used in it, and the loss in manufacture being greater. But it is urged that, as the cartridge-case is capable of being fired many times, it is, in the end, cheaper than a once-fired Boxer cartridge. To this there are two answers—first, that the operation of collecting and re-filling empty cartridges is not one which can be carried out by soldiers on service; secondly, that the Boxer construction of cartridge is just as suitable for re-filling as—if not more so than—the solid-metal cartridge. We have ourselves seen these cartridges re-filled and fired as many as thirty-two times. The best authorities are, however, now generally agreed that the operation of re-filling cartridge-cases is not one to be entertained for military purposes, however practicable for sportsmen.

Before proceeding to describe the Boxer, or service cartridge, it may be well to observe in passing that the self-consuming cartridge is not, as is frequently supposed, necessarily cheaper than the metallic cartridge; on the contrary, the Chassepot is a very expensive cartridge, as it is all made by hand. Again, it is generally assumed that loss of time takes place in extracting the empty case of the non-consuming cartridge after firing. This is an error. Even in the Snider the loss of time is inappreciable, and in the improved types of breech-loaders, such as the Martini-Henry, the operation of extracting is combined with that of opening the breech and cocking the arm; there is, therefore, absolutely no loss of time whatever caused by extraction.

The Boxer service cartridge for the Snider rifle (Fig. 3) consists of a case of thin brass, ·005 inch thick, rolled into a cylinder, and covered with paper, by which the coil is cemented together. The coiled case is fitted into a double base-cup of brass, with an iron disc forming the end of the cartridge which abuts against the breech-block of the rifle. The case is secured in its position by means of a rolled paper wad inside, which is squeezed out with great force against the sides of the case. The iron base is attached to the cartridge by means of the copper "cap-chamber," which contains the detonating arrangement; the cap-chamber, being riveted over at each end, holds the base tightly to the cartridge. The ignition is effected by means of a percussion-cap, resting on a small shouldered brass anvil. To explode the cap, it is necessary that the crown of the cap should be indented (by the striker of the rifle, for example), when the detonating composition is brought into contact with the anvil, and the flash passes through the fire-hole at the bottom of the cap-chamber to the powder in the case. The top of the cartridge is closed by means of a small quantity of wool, over which is fitted the bullet. This bullet has four grooves or *cannelures* round it, which serve to carry the wax lubrication, which in this ammunition is distributed in a thin film around the bullet. The construction of the bullet is peculiar, the head as well as the base being hollowed out. The base is hollowed out for the same reason as in the bullet for the muzzle-loading Enfield—viz., for the insertion of a clay plug, by which the bullet will be expanded into the grooves of the rifling. The head of the bullet is made hollow, in order to give the necessary length to the bullet without increasing the weight. The following are the details:—Length of bullet, 1·065"; diameter (without lubrication), ·573"; weight, 480 grains. Length of cartridge, 2·445"; weight, 1 oz. 10 drs. 20 grs.; charge, 70 grains. This bullet, although an ingenious contrivance for overcoming the difficulties inherent in a large bore slow-twist rifle, is the least satisfactory part of this ammunition; and repeated changes have been made, and innumerable experiments, with a view to the adoption of another bullet for this arm. Hitherto the results have been attended with little marked success, and all that can be said is that the present bullet gives an accuracy and general shooting power about equal to that of the old Enfield, and superior to it in one respect—viz., that the wounds inflicted by the hollow-headed bullet are much more severe than those inflicted by the solid-headed bullet.

The conversion of the muzzle-loading arms may therefore be said to have fully answered its purpose. Let no one depreciate the Snider rifle. It is an admirable weapon, and, taken all

round, superior to most of the breech-loading rifles in the hands of other military powers. It is simple, durable, economical, capable of a rapidity of fire of from twelve to eighteen shots per minute, according to the skill of the firer; the extraction of the empty case is effected with ease and rapidity; the ammunition is exceedingly durable, strong, little susceptible to injury by damp, and as cheap, probably, as any equally serviceable ammunition can be made. It is important to notice that one characteristic feature of great excellence in this cartridge is the coiled case. The action of firing causes the case to expand immediately against the sides of the chamber; and this expansion is followed by an instantaneous contraction, by means of which the withdrawal of the empty shell is greatly facilitated. Also, the arrangement of base is especially noteworthy—the solid end, which gives great stability to a part of the cartridge where strength and resistance are required, and which likewise serves for the claw of the extractor to take hold of. The double cup affords the necessary strength round the back end of the cartridge, the part upon which the greatest strain comes, especially if the block of the rifle should happen not to fit very and the accuracy of the weapon leaves much to be desired—so much, indeed, that we find the Germans took advantage of the large number of Chassepots which fell into their hands to arm some of their troops with them. But the Chassepot—as compared, for the sake of example, with the Martini-Henry—is itself also far from a satisfactory arm. The ignition of the needle-gun cartridge is effected by means of a small patch of detonating composition placed at the back of the sabot, into which the needle penetrates when the arm is fired.

The Chassepot cartridge is made of thin paper, covered with thin silk, the latter being intended to secure the blowing out of the whole of the débris of the consumed cartridge when the arm is discharged. The ignition is effected by means of a percussion-cap, into which the needle strikes, disturbing the detonating composition, the flash passing through holes in the crown of the cap. The cap, it will be observed, is presented to the striker in the opposite direction to the cap in the Boxer cartridge, and the ignition is effected by means of a needle, instead of with a blunt piston. To prevent the gas from the exploded cap escaping backwards, the mouth of the cap is covered

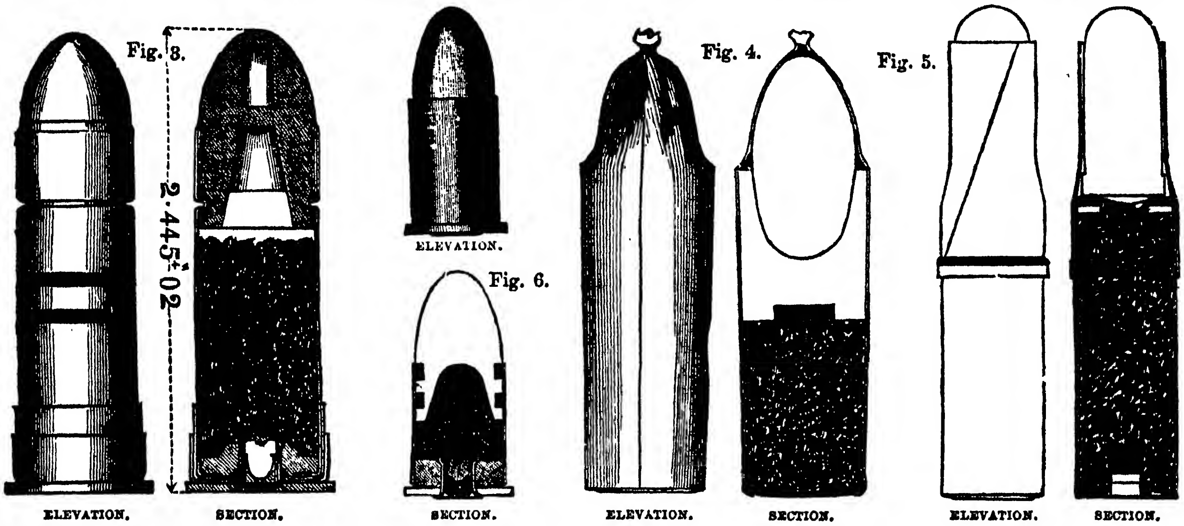


Fig. 3.—BOXER CARTRIDGE FOR SNIDER RIFLE. Fig. 4.—AMMUNITION FOR GERMAN NEEDLE GUN. Fig. 5.—AMMUNITION FOR FRENCH CHASSEPOT. Fig. 6.—BOXER CHARGE FOR BREECH-LOADING REVOLVER.

accurately, or if, from any other cause, the cartridge should be subjected to undue strain round the rim.

Having given a drawing of our own service cartridge, we think that the accompanying drawings of the cartridges for the German needle-gun (Fig. 4) and the French Chassepot (Fig. 5), with the following details as to dimensions, weight, etc., may be of interest for comparison. These are, for German needle-gun:—Length of bullet, 1·08″; diameter, ·533″; weight, 480 grs. Length of cartridge, 2·44″; weight, 1 oz. 6 drs. 20 grs.; weight of charge, 66 grs. For French chassepot:—Length of bullet, 1·″; diameter, ·463″; weight, 380 grs. Length of cartridge, 2·64″; weight, 1 oz. 2 drs. 2 grs.; weight of charge, 85 grs.

The needle-gun cartridge is made of paper. Rotation is given to the bullet by means of a paper sabot, which, being slightly larger than the bore, is forced into the rifling. The bullet thus does not touch the bore at all, but is spun by means of the sabot. This method is a clever plan for obtaining the advantages of a large bore, in respect of shortness of cartridge, prompt ignition of the charge, etc., while preserving the advantages of a small bore as far as the bullet is concerned. But the needle-gun is not at all a satisfactory arm, considered as an arm of precision or as a breech-loader. The liability, under the latter head, to escape of gas at the breech, has been before remarked upon; in addition, the mechanism is defective in some important particulars. As an arm of precision, the weapon is feeble. The velocity imparted to the bullet is small —only about 1,000 feet per second, as against 1,390 for the Chassepot, 1,260 for the Snider, and 1,335 for the Martini-Henry; the trajectory is consequently high, the range is small, with a thin disc of india-rubber, through which the needle passes. Sometimes this india-rubber comes back with the needle, interfering with its action. This is one of the minor defects of the system. There are several other defects too numerous to be here enumerated, but to which the French have become fully alive.

Other means of igniting breech-loading cartridges have been designed. There is the well-known "pin-fire," in which a blunt pin which projects from the cartridge, and one end of which rests in a percussion-cap inside the cartridge, is driven down into the cap composition by the hammer of the gun. There is also the "rim-fire" cartridge, a common American form, in which the fulminate is enclosed in the rim of the base of the cartridge. This method is objectionable on many accounts. Then, of "central-fire" cartridges, of which the Boxer is an example, there are infinite varieties; but the system of cap and anvil is the one most generally in vogue. It is hardly possible to doubt, however, that this detail will in time be considerably simplified and improved upon.

We will mention in this paper one other description of breech-loading cartridge, and one only—namely, the service cartridge for the breech-loading revolver. The construction of this cartridge is sufficiently exhibited in Fig. 6. This ammunition has now entirely superseded the old skin or paper revolver cartridge, which was in vogue until a few years ago. The pistol with which it is used in Her Majesty's service is an Adams revolver—a simple, strong, quick, serviceable weapon. In our next paper we propose to treat of the Martini-Henry breech-loader and its ammunition, and to bring the subject of Small Arms to a conclusion.

VEGETABLE COMMERCIAL PRODUCTS.—IX.

NUTS (*continued*).

WALNUT (*Juglans regia*, L.; natural order, *Juglandaceæ*).—This fine tree is too well known to need description. It grows not only in England, but over the whole of Europe, and in Asia. It is especially abundant in Circassia, where it is extensively cultivated. There is a considerable number of English walnuts in the market, as the fruit ripens well in the southern parts of this country. We receive about 30,000 bushels of foreign walnuts annually, chiefly from Germany, France, and Italy. Walnuts will not bear a long kiln-dried, a process which certainly spoils them.

HICKORY AND PECAN NUTS.—We receive from the United States, in small quantities, the hickory nut (*Carya alba*, Nutt.), and the pecan nut (*Carya olivæformis*, Nutt.), both of which belong to the same natural order, *Juglandaceæ*. These nuts have kernels very similar to those of the walnut, but their shells are very different. The hickory nut is smooth, whitish, marked on its exterior with three or four elevated ridges, extremely hard, and smaller than the walnut. The pecan nut is about the size of an olive, which it resembles in shape, as implied by its specific name; its colour is a light reddish-brown.

BRAZIL NUT (*Bertholetia excelsa*, Humboldt; natural order, *Lecythidaceæ*).—Large fine trees, often 120 feet in height, and growing abundantly in the Brazilian forests. The nuts are closely packed in a hard woody capsule, to the number of twelve or twenty. This capsule is nearly round, but slightly pear-shaped, and is so hard and heavy that when ripe it is dangerous to pass under the trees, for a human head is not thick enough to fracture if it be struck by one of these fruits in falling. capsules open at the top by a circular lid, whence they have been called monkey-pots. Sometimes, as soon as the falling capsule strikes the ground it b the signal for an amusing scramb amongst the monkeys, who, keeping sentinel on a hundred b: instantly swing themselves from tree to tree by the help of their prehensile tales, until they arrive at the spot, and then fight furiously for the coveted nuts. The Indians, in order to obtain the nuts, pelt the monkeys with stones, who in return gather the capsules to hurl at their opponents. In this manner large quantities are collected and transferred to boats, and thence to vessels. We receive from the Brazils annually not less than 50,000 bushels of these nuts.

THE WALNUT-TREE (JUGLANS REGIA).

CHESTNUT (*Castanea vesca*, L.; natural order, *Cupuliferæ*).—The chestnut-tree is a native of Great Britain and the temperate parts of Europe, but the nuts not coming to perfection in this country, we import nearly all that we use from Spain, whence they are usually called Spanish chestnuts. Many thousands of bushels are annually imported. Although not very nutritious, chestnuts are much more easy of digestion when roasted. The larger and better sort called Marones are the produce of Italy, France, Switzerland, and of some parts of Germany.

SWEET (*Amygdalus communis*, L.; variety, *dulcis*; natural order, *Rosaceæ*).—The almond-tree, a native of the warm parts of Asia, and of the coasts of Barbary, is now cultivated to some considerable extent in Southern Europe, especially in Italy and Spain. It grows to about the size of a common plum-tree. The cortex or outer envelope of the fruit is not succulent like the peach (*Amygdalus persica*, L.), to which the almond is allied, but hard, green, and juiceless, so that when growing it looks not unlike an unripe apricot; when fully ripe this green covering splits, and the almond in its rough shell drops out. There are two well-marked varieties of the sweet almond. (1.) The Jordan almonds, the finest and best of the sweetest variety; these, notwithstanding their Oriental name, we receive from Malaga, imported without their shells. (2.) The Valentia almonds, which are broader and shorter than the Jordan variety, and usually imported in the shell. England receives yearly l--- quantities of this fruit, which is usually eaten with raisins.

BITTER ALMOND (*Amygdalus communis*, L.; variety, *amara*).—This variety comes to us from Barbary, in Northern Africa, where it forms a staple article of trade. It is principally used for its oil, which imparts a pleasant flavour to confectionery. This almond is smaller and much rounder than the two preceding varieties of sweet almond, and very bitter to the taste. The annual imports are very considerable.

THE PALM FAMILY (NATURAL ORDER PALMACEÆ).

The palms, next to the cereal grasses and sugar-cane, are the most valuable order of food-plants. They are, however, of far greater importance in the countries where they are produced than in our own, furnishing as they do to the inhabitants of

those countries food, shelter, and clothing. The most useful plant of this order is

THE COCOA-NUT PALM (*Cocos nucifera*, L.).—This palm supplies the natives of the countries in which it grows with clothing, food, medicine, houses, and every description of domestic utensil. The aspect of the tree is very imposing. Its stem is tall and slender, without a branch, and at the top are seen from ten to two hundred cocoa-nuts, each as large as a man's head; over these are the gracefully drooping, green, glossy, and beautiful fronds. "The blessings it confers are incalculable. Year after year the islander reposes beneath its shade, both eating and drinking of its fruit; he thatches his hut with its boughs, and weaves them into baskets to carry his food; he cools himself with a fan plaited from the young leaflets, and shields his head from the sun by a bonnet of its leaves; sometimes he clothes himself with the cloth-like substance which wraps round the base of the stalks, whose elastic rods, strung with filberts, are used as a taper. The larger nuts, thinned and polished, furnish him with a beautiful goblet, the smaller ones with bowls for pipes; the dry husks kindle his fires, their fibres are twisted into fishing-lines and cords for his canoes. He heals his wounds with a balsam compounded from the juice of the nut, and with the oil extracted from it embalms the bodies of the dead. The noble trunk itself is far from being valueless. Sawn into posts, it upholds the islander's dwelling; converted into charcoal, it cooks his food; and supported on blocks of stone, rails in his lands. He impels his canoe through the water with a paddle of the wood, and goes to battle with clubs and spears of the same hard material."*

The cocoa-nut palm grows by the sea-side in most tropical countries, and is usually the first plant to establish itself on the newly-formed coral reefs in the Pacific and Indian Oceans. It is abundant throughout the South Sea Islands. The fibrous outer covering of the nut, when macerated and prepared, is termed *coir*, a substance extensively employed for making ropes, mats, and stuffing for cushions. Large quantities of oil are obtained from the nut, after it has been ground into a rough meal, called in Ceylon *coperah*. This oil has of late years been in great demand in England for the manufacture of composite candles and soap. Marine soap, so called because it washes linen with sea-water, is made from cocoa-nut oil. This nut is used largely in confectionery. The cocoa-nut forms a considerable article of export from many of the British colonies, several millions being imported into the United Kingdom every year.

VII. MISCELLANEOUS FOOD PLANTS.

ONION (*Allium cepa*, L.; natural order, *Liliaceæ*).—The onions of Spain and Portugal and the south of France are superior to our common garden onion, larger, and more succulent; we therefore import them from those countries in chests and boxes to the amount of about 700 or 800 tons.

SOYBEAN (*Soja hispida;* natural order, *Leguminosæ*).—A sauce or catsup, as thick as treacle and of a clear black colour, called soy, which is much esteemed, is made from the beans of this plant by the Chinese, and sent to us from India in considerable quantities. From 500 to 600 gallons are annually imported.

TRUFFLES (*Tuber cibarium;* natural order, *Fungi*).—These remarkable fungi grow beneath the soil, generally in beech woods, in this country somewhat sparingly, but more plentifully in France and Italy. The truffles of commerce, besides the above species, include several others, all of which are edible, and highly prized for their delicate flavour. In form the truffle is round, its surface in some species smooth, in others warted and tuberculous; the colour, dark-brown outside, and brown, grey, or white within. They generally grow at the depth of five or six inches. Dogs are trained to scent them out, and sows are also employed for the same purpose. We receive them from France and Italy preserved in oil. They are used generally in sauces and soups, and as stuffing for poultry.

MOREL (*Morchella esculenta*, Dill.).—This is one of the few fungi found in this country which may be eaten with safety. The stipes or stalk is hollow, from two to three inches high; the pileus or cap is spheroidal, hollow within, and marked on the surface with numerous areolæ resembles a honeycomb in structure; the colour whitish.

The morel is usually found abundantly where trees have been burnt, a fact which led in Germany to the practice of firing the forests for the sake of the morels, a practice so injurious that it became necessary to suppress it by law. This fungus occasionally occurs in woods and orchards in England, whence it finds its way to our markets; it is found to be very valuable for cookery purposes, but is more frequently used in a dry state for sauce than when fresh. We import the greater proportion of the morels used in England from Italy.

CARRAGEEN OR IRISH MOSS (*Chondrus crispus;* natural order, *Algæ*).—This is a very common plant on the rocky coasts of Ireland and Great Britain. The frond is tufted, fixed to the rock by a hard scutate base, dichotomous, the segments linear, wedge-shaped, frequently crisped and curled at the edges. The whole plant looks like yellow parchment.

Carrageen or Irish moss is sold by all druggists and herbalists in the United Kingdom. It contains an abundance of gelatine, and is extensively used for feeding cattle, and for forming a light nutritive jelly for invalids, nearly the whole weight of the plant being convertible by boiling into the required substance. Carrageen moss is sometimes used in manufactories for dressing silks. Immense quantities of it are annually brought to England from the Irish coast, and from Northern Europe. A preparation of this moss is now sold under the name of Sea-Moss Farine, which is coming into very general use. The moss is apparently dried, and then ground or crushed into a kind of meal, resembling fine sand. The jelly obtained from this plant is made far more quickly from the meal than it is by boiling the moss in an entire state.

We have now considered the principal, if not all, of the plants used for food, and some other purposes in commerce, in the lessons that have been brought under the notice of the reader. In our next lesson on this subject we shall commence a review of plants that are of importance in medicine and many of the industries of the United Kingdom, commencing with textile plants, or those from which we derive materials for clothing and cordage.

APPLIED MECHANICS.—VI

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COMMON TOOLS: THE HAMMER, SAW, FILE, AND CHISEL.

THE HAMMER.

THIS very well-known tool is a remarkable mechanical power. The study of its action is important, as it depends on some principles of the greatest consequence. We shall commence by an explanation of these principles, and we shall then apply them to certain different forms of hammer, reserving, however, the important subject of the steam-hammer for a separate lesson.

We shall suppose that a hammer is employed for driving a nail into wood, and let us examine what is the resistance to be overcome by the nail, and compare it with the power which is applied to the hammer.

In considering this subject, it is necessary to understand the structure of wood. Wood is composed of multitudes of fibres placed side by side. In this it differs from stone, which is a multitude of particles merely attached together. This constitution of wood is the cause of many of its peculiar properties. The fibres are extremely tenacious in themselves, but they adhere together with comparatively weak force. This produces what is called the grain in wood. If I take a piece of pine one foot long and one inch square, I should find it impossible to break it when the fibres—that is, the grain—run along the length of the wood; the reason of this is, that to break the piece the fibres would have to be torn across, and enormous force would be required. But if I take a piece of pine of the same dimensions, in which the grain runs across the wood, I find that it is broken with comparative ease. The reason is that in this case the fibres have not to be torn asunder, but only separated, and the force of adhesion is not great. In different woods, the grain varies, the fibres being much more compact in some cases than

* Melville's "Adventures in the South Seas."

in others. Splitting of wood is just the separating of contiguous fibres. In fact, a piece of wood is to some extent analogous to a rope, the fibres in each being placed side by side; the difference lies in this, that in the first place the fibres of wood are not twisted like those of the rope, and in the second place that the fibres of the wood adhere together, while those of the rope do not. The fibres of wood are also short. Wrought-iron, when rolled into bars, presents somewhat of a fibrous structure in the direction of its length; this is seen when one of these bars is torn asunder.

The nail has two completely different resistances to overcome. It has, in the first place, to compress the fibres of the wood, so as to make a hole for its entry. After it has entered, as it is somewhat of a taper form, while the point is dividing the fibres and compressing them on each side, the sides of the nail must still be compressing the fibres, as the hole has to be made larger and larger, to admit the tapering nail. One part, then, of the force of the hammer is expended upon compression of the fibres; but there is another force to be overcome by the nail, and that is the friction against the sides of the hole—the nail is pressed with great force against the wood, and there is, therefore, a great deal of friction produced. The relative amounts of these forces it is not easy to determine; it is probable that in hard woods the first is the most important, while in very soft woods the proportion which the latter bears to the former is doubtless greater, but both added together produce a very large amount of force, which has to be overcome by the blows of the hammer.

Before driving a nail into wood it is often usual to bore a hole for it with a bradawl, and the exertion of making a hole is a measure of the resistance produced by compression of the fibres. The extremity of the bradawl is bevelled, as shown in Fig. 1. This bevelled edge must, as every one knows, be placed at right angles to the grain of the wood. When pressed downwards it divides the fibres, and then compresses them in the direction of the length of the fibres. In so doing, there is little tendency to split the wood, for the wedge-shaped extremity is never employed in forcing the fibres apart. But if the edge of the bradawl be placed parallel to the fibres, then as the wedge enters it forces the fibres apart; and if it be easier to split the wood than to compress the fibres together, the former catastrophe happens. The resistance of the wood to splitting is measured by the area of the surfaces which would have to be separated; hence in the middle of a large piece of timber splitting will not occur, however the bradawl be introduced, because, though the resistance of the fibres to compression is still as great as before, yet the resistance to splitting has increased and is greater than the resistance to compression.

Fig. 1.

The hole having been bored for the reception of the nail, the amount of work to be done by the hammer is diminished until the nail completely fills the hole, and then, of course, the further resistance is the same as if no hole had been bored.

In order to express the amount of force which the hammer exerts upon the nail, we must consider what weight must be laid upon the head of the nail in order to force it into the wood. This force must evidently be enormous. A nail requires a very large force to pull it out, when friction alone is retaining it, and to force it in must of course require a very much larger force. We may, therefore, be assured that a force at all events of some hundredweights would have to be laid upon the head of a two-inch nail, in order to force it into the wood. It is, of course, meant that the pressure of this weight is to be simply borne by the nail: we do not mean that the head is to receive a blow with this amount; it would, of course, not be possible to place a heavy load on the head of the nail directly; we must produce the effect by means of levers, or some similar contrivance.

Now the head of the hammer must be capable, when it delivers a blow upon the head of the nail, of developing a force for a short time equal to the continued pressure that would be produced by a load of many hundredweights; hence the hammer is a mechanical power, for it transforms the power of the hand into a far larger force. What is the cause of this property of the hammer? It depends upon a remarkable force called the force of inertia, and may also be viewed in connection with the principle of work to which we have already so often referred. We shall first consider it in the former aspect, and afterwards in the latter.

To set a body in motion requires the exertion of force. This is so evident, following as it does from the definition of force, that it is not necessary to dwell upon it. To set the head of the hammer in motion the force of the hand is required. But when a body has been set in motion, it requires force to stop it. This is nearly as evident as the former statement. When a railway train is in motion, it would require a prodigious force to stop it. When a stone drops upon the ground, it is stopped by the force of reaction which the ground exerts upon it. In short, to change the condition of a body as to arrest a motion requires the exertion of force. Now action and reaction are equal and opposite; this is a profound law of Nature not always easy to comprehend. In the present case it asserts that when any force acts upon a body to stop it, the body reacts with an equal force upon the body which endeavours to stop it.

Hence, when the head of the hammer comes into contact with the nail, the head of the nail acts upon the hammer, and the hammer reacts upon the nail. This force of reaction may be enormously great. The amount of the force depends upon the amount of motion which the nail makes. If the nail move but a very small way, the force is great; but if the nail yields easily, the force is comparatively small. This will be evident from the obvious circumstance, that a rapidly moving body exerts a prodigious force of reaction upon any body which endeavours to stop it suddenly, but if the body be stopped gradually it exerts a much less force.

But the action of the hammer may be viewed in another way, which will perhaps make the matter clearer. Work or energy, as we have already explained it, may be stored up in a moving body. Thus, for example, a cannon-ball when in motion has a quantity of energy imparted to it by the explosion of the gunpowder; this energy is stored in it until the cannon-ball meets a wall or other obstacle, the energy is then instantly transferred to the destruction of what is opposed to it, and the ball, having spent its energy, comes to rest. That work is actually in the ball may be at once realised, if we remember that a cannon-ball might be shot straight up into the air. Thus, suppose a ball of 100 lb. weight ascended 1,000 feet, the ball contained sufficient energy to accomplish

$$100 \times 1{,}000 = 100{,}000$$

foot-pounds of work. Whatever be the moving body, the way to estimate the quantity of energy it contains is to see how high in the air its velocity would raise it.

If a body were moving with a certain velocity, the laws of Mechanics tell us that the height to which it would ascend if projected vertically upwards with that velocity is

$$\frac{(\text{velocity})^2}{64}$$

If, therefore, we multiply this height by the mass of the body, we have as product the number of units of work that the body is capable of doing before it comes to rest.

Let us apply these considerations to the case of the hammer. We shall suppose a hammer, the head of which weighs 1 pound. Now the head of the hammer is not merely allowed to fall upon the nail, but is impelled downwards upon it by a considerable velocity. We may suppose, at all events, that when the head of the hammer reaches the nail, it is at that instant moving with a velocity of 20 feet per second. Now, by the rule already given, a body projected vertically upwards with a velocity of 20 feet per second would ascend to a height—

$$\frac{(20)^2}{64} = \frac{400}{64} = 6{\cdot}2 \text{ feet.}$$

This is certainly within the mark, for it is probable the velocity exceeds 20 feet. The quantity of work stored in the hammer is, then, sufficient to raise 1 lb. 6·2 feet high, or, in other words, the hammer contains 6·2 units of work. All this work is expended upon the nail, and let us suppose that the nail is forced into the wood one-tenth of an inch by one blow. The nail must then react upon a hammer with a sufficient force to consume the entire 6·2 units of work when the hammer moves through one-tenth of an inch.

Let F be the force with which the hammer and nail react on each other, then the number of units of work done in forcing the nail into the wood is

$$F \times 0{\cdot}1'' \div 12;$$

but this must be equal to the number of units of work which the hammer expends, hence we must have

$$F \times 0{\cdot}1'' \div 12 = 6{\cdot}2,$$

from which we find

$$F = 744.$$

Hence the pressure exerted on the head of the nail is at least 744 lb. This is a very large force, equal to a third of a ton.

But supposing the nail had only entered 0·05″, we shall easily find by the same process that the pressure exerted is 1,488 lb. Hence we see that, according as the wood is harder—that is, according as the nail enters less at each stroke—the force of the blow becomes greater. Thus the hammer is a mechanical power most admirably adapted for the purposes it fulfils.

The pile-driver is an example of the hammer which is well adapted to illustrate these principles. A pile is a large piece of timber, shod at one end with an iron point, and provided with a hoop of iron surrounding it at the other end; the pointed end is forced into the ground by means of heavy blows delivered upon the other end. The mode in which these blows are given is extremely simple. A massive iron weight, called a "monkey," slides up and down on a vertical frame, by means of a lifting crab or a steam-engine; this weight is raised to a considerable height, and then let fall upon the head of the pile; these blows are repeated until the pile has been driven so far that the blows produce but little effect. Now, if we suppose that the mass of the monkey in a pile-engine is 500 lb., and that the monkey is raised to a height of 20 feet, and then allowed to fall, the number of units of work that have been stored up in the monkey, and which it is therefore capable of exerting, is

$$500 \times 20 = 10{,}000.$$

Hence 10,000 units of work will be expended upon the pile. Now suppose that the pile be only driven 1″ into the ground by the blow. Let us calculate the pressure which has been exerted. Since 1″ is one-twelfth of a foot, we have for the force F

$$\tfrac{1}{12} F = 10{,}000; \quad \therefore F = 120{,}000.$$

Hence the pile is urged downwards for the space of 1″ by a pressure of 120,000 lb., that is, a force of upwards of 50 tons.

When the pile has been driven some distance, it moves less and less under each blow; consequently, as we have already explained, the magnitude of the force which each blow produces is increased. When the pile "refuses," as it is technically termed, we are then assured that it can withstand a force of enormous magnitude, and, therefore, is capable of supporting the buildings or whatever else the pile may be intended to sustain.

THE SAW.

The ancients probably employed the simple process of splitting for the purpose of dividing timber; but such a process is wasteful, both of material and time. This rude method has been replaced by the saw, which, in different forms, is doubtless the most important tool used in the working of wood. We shall afterwards return to the subject of the machinery used in saw-mills, and therefore we shall not here discuss the circular saw and other special applications of the saw, but shall confine ourselves to a general sketch of the process of sawing.

We have already described the structure of wood as consisting of multitudes of fibres placed side by side. In sawing a piece of wood with the grain, the teeth of the saw tear away these fibres without necessarily cutting them across; in sawing against the grain, however, the fibres have actually to be divided. This is the reason why a saw used for cutting along the grain, called a hand-saw, has larger teeth than a saw which is used for cutting against the grain, called a tenon-saw. The method of sawing is also applicable to other materials besides wood. Marble and other soft stones are frequently cut by saws specially adapted for the purpose. In these cases the sawing is really accompanied by a grinding process. The particles of stone which are removed are comminuted into very small particles.

Some very valuable remarks upon saws and other tools are to be found in Holtzappfel's treatise on "Turning and Mechanical Manipulation." From this work the following account is condensed:—

"The blade of the saw is a thin plate of steel rolled of equal thickness; the teeth are then punched along its edge previously to the blade being hardened and tempered. After this process the saw is flattened by hammering. The blade is then ground upon a grindstone of considerable diameter, and principally crossways, so as to reduce the thickness of the metal from the teeth towards the back. When, by means of the hammer, the blade has been rendered of uniform tension or elasticity, the teeth are sharpened with a file, and slightly bent to the right and left alternately, in order that they may cut a groove so much wider than the general thickness as to allow the blade to pass freely through the groove made by itself. The bending is called the 'set' of the saw. The angles of the points of the saw-teeth are more acute in proportion to the softness of the material to be sawn.

"In using the hand-saw, the left hand is applied to the board, in order that the end of the thumb may be placed just above the teeth and against the smooth blade of the saw, to guide it to the line. The saw is then drawn backwards and forwards a few times with light pressure, to make a slight notch. In the first few strokes the length and vigour of the stroke of the saw are gradually increased, until the blade has made a cut of two to four inches in depth, after which the entire force of the right arm is employed, the saw is used from point to heel, and, in extreme cases, the whole force of both arms is used to urge the saw forwards.

"In order to acquire the habit of sawing well, or, in fact, of performing well most mechanical operations, it is desirable to become habituated to certain definite positions; thus, in sawing, it is better the work should as often as practicable be placed either exactly horizontal or vertical; the positions of the tools and the movements of the person will then be constantly either horizontal or vertical, instead of arbitrary and inclined."

THE FILE.

This useful tool depends for its action upon the same principles as the action of the saw. The file is composed of a piece of steel which has first been roughened by a special process called file-cutting, and then rendered intensely hard. The file is used for removing small quantities of metal from a surface. The work is held firmly in a vice, and the file is moved backwards and forwards by the workman. Simple as the process of filing appears to be, a great deal of skill is demanded in order to do work with it as it should be done. The ridges on the file detach small particles of the work; the finer the file, the smaller are the particles which are removed. Polishing with rouge is in reality a process of filing; the particles of rouge are extremely small and extremely hard, and they remove extremely small particles of the surface, and thus polish it, for a polished surface is not absolutely smooth. When magnified, it is seen to be rough, but the irregularities are very small; the rouge removes all irregularities above a certain magnitude.

Holtzappfel thus describes the manufacture of files:—"The pieces of steel or the blanks intended for files are forged out of bars of steel that have been either tilted or rolled as nearly as possible to the sections required, so as to leave but little to be done at the forge; the blanks are afterwards annealed with the greatest caution, so that in none of the processes the temperature known as the blood-red heat may be exceeded. The surfaces of the blanks are now rendered accurate in form and quite clean in surface, either by filing or grinding. In Warrington, where small files are made, the blanks are mostly filed into shape, as the more exact method. In Sheffield, it is customary, in the manufacture of large files, to grind the blanks on the grindstone as the more expeditious method; but the best of the small files are here also filed into shape, and in some few cases the blanks are placed in the planing machine for those called *dead parallel* files, the object being in every case to make the surface clean and smooth. The blank before being cut is slightly greased, that the chisel may slip freely over it, as will be explained. The file-cutter when at work is always seated before a square block or anvil, and he places the blank straight before him, with the tang towards his person; the ends of the blank are held down by the leather straps or loops, one of which is held fast by each foot.

"The ridges are cut by means of a chisel, which, for larger files, at Sheffield, is 3 inches long, 2½ inches wide, and has a cutting-edge at an angle of 50°. The first cut is made at the point of the file; the blow of the hammer upon the chisel causes the latter to indent and slightly drive forwards the steel, thereby throwing up a trifling ridge or burr. The chisel is im-

mediately replaced upon the blank, and slid from the operator until it encounters the ridge previously thrown up, which arrests the chisel, or prevents it from slipping further back, and thereby determines the succeeding position of the chisel. The heavier the blow the greater the ridge, and the greater the distance from the preceding cut at which the chisel is arrested. The chisel having been placed in its second position is again struck by the hammer, which is made to give the blows as nearly as possible of uniform strength; and the process is repeated with considerable rapidity and regularity, sixty to eighty cuts being made in one minute, until the entire length of the file has been cut with inclined, parallel, and equidistant ridges, which are collectively denominated 'first course.' So far as this one face is concerned, if the file is intended to be single-cut, it would then be ready for hardening. Most files are, however, double-cut, or have two courses of chisel cuts; and for those the surface of the file is now smoothed, by passing a smooth file once or twice along the face of the teeth, to remove only so much of the roughness as would obstruct the chisel from sliding along the face in receiving its successive positions, and the file is again greased. If the file is flat, and to be cut on two faces, it is now turned over, but to protect the teeth from the hard face of the anvil a thin plate of pewter is interposed. In cutting files they almost always become more or less bent, and there would be danger of breaking them if they were set straight while cold; they are consequently straightened whilst they are at the red heat, immediately prior to their being hardened and tempered. Previously to their being hardened, the files are drawn through beer-grounds, yeast, or other sticky matter, and then through common salt, mixed with cows'-hoof, previously roasted and pounded, and which serves as a defence to protect the delicate teeth of the file from the direct action of the fire. The compound likewise serves as an index of the temperature, as on the fusion of the salt the hardening heat is attained. The file thus prepared is gradually raised to a dull red, and is then straightened with a leaden hammer on two small blocks of lead; the temperature is afterwards increased until the salt just fines, when the file is immediately dipped in water. The tangs are next softened, to prevent their fracture: this is done by immersing the tang in a bath of melted lead. The tang is afterwards cooled in oil. When the file has been cleaned it is fit for use."

THE CHISEL.

This tool depends for its action upon principles very different from those of the saw or file. We take the chisel as the type of a cutting tool, and we must first consider in what the act of cutting consists. We shall again borrow from the admirable authority (Holtzappfel) already referred to:—

"If we drive an axe or a thin wedge into the centre of a block of wood, it will split the same into two parts, through the natural line of the fibres, leaving rough uneven surfaces, and the rigidity of the mass will cause the rent to precede the edge of the tool. The same effect will partially occur when we attempt to remove a stout chip from off the side of a block of wood with the hatchet, adze, paring-knife, chisel, or any similar tool. So long as the chip is too rigid to bend to the edge of the tool, the rent will precede the edge, and with a naked tool the splitting will only finally cease when the instrument is so thin and sharp, and it is applied to so small a quantity of the material that the shaving can bend to the tool, and then only will the edge be cut, or will exhibit a true copy of the edge of the instrument, in opposition to its being split or rent, and consequently showing the natural disruption or tearing asunder of the fibres."

"For paring a large or nearly horizontal surface, the adze is the proper instrument to be employed. The tool is held in both hands, whilst the operator stands upon his work in a stooping position; the handle being from twenty-four to thirty inches long, and the weight of the blade from two to four pounds.

"The adze is swung in a circular path almost of the same curvature as the blade, the shoulder-joint being the centre of motion, and the entire arm and tool forming as it were one inflexible radius. The tool, therefore, makes a succession of small arcs, and in each blow the arm of the workman is brought in contact with the thigh, which thus serves as a stop to prevent accidents. In coarse preparatory works, the workman directs the adze into the space between his two feet; he thus surprises us by the quantity of work removed. In fine works he frequently places his toes over the spot to be wrought, and the adze penetrates two or three inches beneath the sole of his shoe, and he thus surprises us by the apparent danger yet perfect working of the instrument, which, in the hands of the shipwright in particular, almost rivals the joiner's plane; it is with him the nearly universal paring instrument, and is used upon works in all positions."

"The chisel when inserted in one of the several forms of stocks or guides becomes the plane, the general objects being to limit the extent to which the blade can penetrate the wood, to provide a definitive guide to its path or direction, and to restrain the splitting in favour of the cutting action."

"It is well known that most pieces of wood will plane better from one end than from the other, and that when such pieces are turned over they must be changed end for end likewise. The necessity for this will immediately appear if we remember the fibres of which the wood is composed. It rarely happens that the fibres will be exactly parallel to the face of the work; the plane, then, when working with the grain, would cut smoothly, as it would rather press down the fibres than otherwise, whereas when the plane is used in the other direction it will meet the fibres cropping out, and be liable to tear them up."

"The handsome characters of showy woods greatly depend upon all kinds of irregularities in the fibres, so that the direction in which the plane should be applied is continually changing. Even the most experienced workman will apply the smoothing-plane at various angles across the different parts of such wood according to his judgment. In extreme cases, when the wood is very knotty, the plane can scarcely be used at all, and such pieces are finished with the steel scraper."*

PRINCIPLES OF DESIGN.—VIII.

By Christopher Dresser, Ph.D., F.L.S., etc.

SOME GENERAL ART PRINCIPLES.

I intended devoting this chapter to the consideration of furniture, and of the art principles which are involved in its formation; but I feel that there are principles which have not yet been considered that are so important, and of such general application, that I cannot pass to consider any one art manufacture till those have been considered.

The first principle to which I must ask your attention is *utility*, for the first aim of the designer of any article must be to render the object which he produces useful. I may go further and say, that an article must be made not only useful, but as perfectly suited to the purpose for which it is intended as it can be. It matters not how beautiful the object is intended to be; it must first be formed as though it were a mere work of utility, and, after it has been carefully created with this end in view, it may then be rendered as beautiful as you please.

There are special reasons why our works should be useful as well as beautiful, for if an object, however beautiful it may be in shape, however richly covered with beautiful ornaments, or however harmoniously coloured, be unsuitable for use, it will ultimately be set aside, and that which is more convenient for use will replace it, even if the latter be without beauty. As an illustration of this fact, let us suppose the balustrade railings of a staircase very beautiful, and yet furnished with such projections as render it almost impossible that we walk up or down the stairs without tearing our dress, or injuring the person, and how soon will our admiration of the beautiful railing disappear, and even be replaced by hatred!

In relation to this subject, Professor George Wilson has said: "The conviction seems ineradicable from some minds, that a beautiful thing cannot be a useful thing, and that the more you increase the beauty of the necessary furniture or the implements of every-day life the more you lessen their utility. Make the Queen's sceptre as beautiful as you please, but don't try to beautify a poker, especially in cold weather. My lady's vinaigrette carve and gild as you will, but leave untouched my pewter inkbottle. Put fine furniture, if you choose, into my drawing-room; but I am a plain man, and like useful things in my parlour, and so on. Good folks of this sort seem to labour

* In this connection the student will derive very great assistance from Professor R. H. Smith's "Cutting Tools worked by Hand and Machine," in Messrs. Cassell and Company's series of Technological Manuals.

under the impression that the secret desire of art is to rob them of all comfort. Its unconfessed but actual aim, they believe, is to realise the faith of their childhood, when it was understood that a monarch always wore his crown, held an orb in one hand and a sceptre in the other, and a literal interpretation was put upon Shakespeare's words,

"'Uneasy lies the head that wears a crown!'

Were art to prosper, farewell to fire-proof, shapeless slippers, which bask like salamanders unharmed in the hottest blaze. An æsthetic pair, modelled upon Cinderella's foot, and covered with snow-white embroidery, must take their place, and dispense chilblains and frost-bite to miserable toes. Farewell to shooting-coats out a little at the elbows, to patched dressing-gowns, and hair-cloth sofas. Nothing but full dress, varnished boots, spider-legged chairs, white satin chair-covers, alabaster ink-bottles, velvet door-mats, and scrapers of silver or gold. It is astonishing how many people think that a thing cannot be comfortable if it is beautiful. . . . If there be one truth which the Author of all has taught us in His works more clearly than another, it is the perfect compatibility of the highest utility with the greatest beauty. I offer you one example. All are familiar with the beautiful shell of the nautilus. Give the nautilus itself to a mathematician, and he will show you that one secret of its gracefulness lies in its following in its volute or whorl a particular geometrical curve with rigid precision. Pass it from the mathematician to the natural philosopher, and he will show you how the simple superposition of a great number of very thin transparent plates, and the close approximation of a multitude of very fine engraved lines, are the cause of its exquisite pearly lustre. Pass it from the natural philosopher to the engineer, and he will show you that this fairy shell is a most perfect practical machine, at once a sailing vessel and a diving-bell, in which its living possessor had, centuries before Archimedes, applied to utilitarian ends the law of specific gravity, and centuries before Halley had dived in his bell to the bottom of the sea. Pass it from the engineer to the anatomist, and he will show you how, without marring its beauty, it is occupied during its lifetime with a most orderly system of rowing and sailing tackle, chambers for food, pumps to keep blood circulating, ventilating apparatus, and hands to control all, so that it is a model ship with a model mariner on board. Pass it lastly from the anatomist to the chemist, and he will show you that every part of the shell and the creature is compounded of elements, the relative weights of which follow in each individual nautilus the same numerically identical ratio.

"Such is the nautilus, a thing so graceful, that when we look at it, we are content to say with Keats—

'A thing of beauty is a joy for ever;'

and yet a thing so thoroughly utilitarian, and fulfilling with the utmost perfection the purely practical aim of its construction, that our shipbuilders would be only too thankful if, though sacrificing all beauty, they could make their vessels fulfil their business ends half so well."

Viewing our subject in another light, and with special reference to architecture, we notice that unless a building is fitted for the purpose intended, or, in other words, answers utilitarian ends, it cannot be esteemed as it otherwise might be, even though it be of great æsthetic beauty. In respect to this subject, Mr. Owen Jones has said, "The nave and aisles of a Gothic church become absurd when filled with pews for Protestant worship, where all are required to see and hear. The columns of the nave which impede sight and sound, the aisles for processions which no longer exist, rood-screens, and deep chancels for the concealment of mysteries, now no longer such, are all so many useless reproductions which must be thrown aside." Further, "As architecture, so all works of the decorative arts, *should possess fitness*, proportion, harmony; the result of all which is repose." Sir Digby Wyatt has said, "Infinite variety and unerring fitness govern all forms in Nature." Vitruvius: "The perfection of all works depends on their fitness to answer the end proposed, and on principles resulting from a consideration of Nature itself." Sir Charles L. Eastlake: "In every case in Nature where fitness or utility can be traced, the characteristic quality, or *relative* beauty, is found to be identical with that of fitness." A. W. Pugin: "How many objects of ordinary use are rendered monstrous and ridiculous simply because the artist, instead of seeking the most convenient form, and then decorating it, has embodied some extravagance to conceal the real purpose for which the article has been made." And with the view of pointing out how fitness for, or adaptation to the end proposed is manifested in the structure and disposition upon the earth of plants, I have written in a little work now out of print: "The trees which grow highest upon the mountains, and the plants which grow upon the unsheltered plain, have usually long, narrow, and rigid leaves, which, owing to their form, are enabled to bear the fury of the tempest, to which they are exposed, without injury. This is seen in the case of the species of fir which grow at great altitudes, where the leaves are more like needles than leaves as they commonly occur; and also in the species of heath which grow upon exposed moors: in both cases the plants are, owing to the form of the leaf, enabled to defy the blast, while those with broad leaves would be shattered and destroyed.

"Not only is the form of leaf such as fits these plants to dwell in such inhospitable regions, but other circumstances also tend to this result. The stems are in both cases woody and flexible, so that while they bend to the wind they resist its destroying influence by their strength and elasticity. In relation to the stem of the papyrus," which is a plant constantly met with in Egyptian ornaments, "Sir W. J. Hooker mentions an interesting fact which manifests adaptation to its position. This plant grows in water, and attaches itself to the margins of rivers and streams, by sending forth roots and evolving long underground stems in the alluvium of the sides of the waters. Owing to its position it is exposed to the influences of the current which it has to withstand, and this it does, not only by having its stems of a triangular form —a shape well adapted for withstanding pressure—but also by having them so placed in relation to the direction of the stream, that one angle always meets the current, and thus separates the waters as does the bow of a modern steam-ship."

I might multiply illustrations of this principle of *fitness*, or *adaptation to purpose*, as manifested in plants, to an almost indefinite extent; but when all had been said, we should yet have but the simple truth before us, that the primary aim which we should have in creating any object, is that of rendering it perfectly fitted to answer the proposed end. If those works which are beautiful were but invariably useful, as they should be; if those objects which are most beautiful were also the most convenient and useful—and there is no reason why they should not be so—how the beautiful would become loved and sought after. Cost would be of little moment, the price would not be complained of, if beautiful objects were works of perfect utility. But, alas! it is far otherwise: that which is useful is often ugly, and that which is beautiful is often inconvenient to use. This very fact has given rise to the highly absurd fashion of having a second poker in a drawing-room set of fire-irons. The one poker is ornamental, possibly, but it is to be looked at; the other is for use, and as it is not to be looked at is hidden away in some corner, or close within the fender. I do not wonder at the second poker being required; for nineteen out of every twenty pokers of an ornamental (?) character which I have seen during the last few years would hurt the hand so insufferably if they were used to break a lump of coal with, that it would almost be impossible to employ them constantly for such a purpose. But why not abolish the detestable thing altogether? If the poker is to be retained as an ornament, place it on the table or chimney-piece of your drawing-room, and not down on the hearth, where it is at such a distance from the eye that its beauties cannot be discovered. It is no use saying it would be out of place in such a position. If to poke the fire with, its place is within the fender; if it is an ornament, it should be placed where it can be best seen—in a glass case, if worthy of protection.

I hope that sufficient has now been said upon this all-important necessity, that if an object is to be beautiful it should also be useful, to cause us to consider it as a primary principle of design that all objects which we create *must* be useful. To this as a first law we shall constantly have to refer. When we construct a chair we shall ask, is it useful? is it strong? is it properly put together? could it be stronger without using more or a stronger material? and then we should consider whether it

is beautiful. When we design a bottle we shall inquire, is it useful? is it all that a bottle should be? could it be more useful? and then, is it beautiful? When we create a gas-branch we shall ask, does it fulfil all requirements, and perfectly answer the end for which it is intended? and then, is it beautiful? And in relation to patterns merely, we shall also have to make similar inquiries. Thus, in drawing a carpet design, we shall inquire, is this form of ornament suitable to a woven fabric? is it suitable to the particular fabric for which it is intended? is the particular treatment of the ornament which we have adopted the best possible when we bear in mind that the carpet has to be walked over, is to act in relation to our furniture as a background does to a picture, and is to be viewed at some distance from the eye? and then, is it beautiful? Such inquiries we shall put respecting any object the formation of which we may suggest: hence, in all our inquiries, I shall, as I love art, consider utility before beauty, in order that my art may be fostered and not despised.

There are many subjects not yet named in these chapters which we ought to consider, but I must content myself by merely mentioning them, and you must be willing to think of them, and consider them with care as their importance may demand. Some of them, however, we shall refer to when considering the various manufactures.

A principle of great importance in respect to design is, that *the material of which an object is formed should be used in a manner consistent with its own nature, and in that particular way in which it can be most easily worked.*

Another principle of equal importance with that just set forth, is this: that *when an object is about to be formed, that material (or those materials) which is most appropriate to its formation should be sought and employed.* These two propositions are of very great importance, and the principles which they set forth should never be lost sight of by the designer. They strike at the very root of successful designing, for if ignored the work produced cannot be satisfactory.

Curves will be found to be beautiful just as they are subtle in character; those which are most subtle in character being most beautiful.

The arc is the least beautiful of curves (I do not here speak of a circle, but of the line, as a line, which bounds the circle); being struck from one centre, its origin is instantly detected; while the mind requires that a line, the contemplation of which shall be pleasurable, must be in advance of its knowledge, and call into activity its powers of inquiry. The elliptic curve, or curve bounding the ellipse, is more beautiful than the arc, for its origin is not so strikingly apparent, being formed around two centres. The curve of the egg is more beautiful still, being formed around three centres. As the number of centres necessary to the formation of a curve increases, the difficulty of detecting its origin also increases, and the variety which the curve presents is also proportionally great; the variety being obviously greater as the number of the centres from which it is struck is increased.

Proportion, like the curve, must be of a subtle nature.

A surface must never be divided for the purpose of decoration into halves. The proportion of 1 to 1 is bad. As proportion increases in subtlety it also increases in beauty. The proportion of 2 to 1 is little better; the proportion of 3 to 8, or of 5 to 8, or of 5 to 13, is, however, good, the last named being the best of those which I have adduced; for the pleasure derived from the contemplation of proportion increases with the difficulty of detecting it. This principle is true in relation to the division of a mass into primary segments, and of primary segments into secondary forms, as well as in relation to grouping together parts of various sizes; hence it is worthy of special note.

A principle of order must prevail in every ornamental composition.

Confusion is the result of accident, order of thought and care. The operation of mind cannot well be set forth in the absence of this principle; at least, the presence of a principle of order renders the operation of mind at once manifest.

The repetition of parts frequently aids in the production of ornamental effects.

The kaleidoscope affords a wonderful example of what repetition will do. The mere fragments of glass which we view in this instrument would altogether fail to please were they not repeated with regularity. Of themselves repetition and order can do much.

Alternation is a principle of primary importance in certain ornamental compositions.

In the case of a flower (as the buttercup, or chickweed, for example), the coloured leaves do not fall over the green leaves (the petals do not fall over the sepals), but between them—they alternate with them. This principle is not only manifested in plants, but also in many ornaments produced in the best periods of art.

If plants are employed as ornaments they must not be treated imitatively, but must be conventionally treated, or rendered into ornaments.

A monkey can imitate, man can create.

These are the chief principles which we shall have to notice, as involved in the production of ornamental designs.

The next paper will be devoted to the consideration of art furniture, but in it we shall have to discuss questions involved in the construction of all art objects.

TECHNICAL DRAWING.—XVIII.

DRAWING FOR MACHINISTS AND ENGINEERS.

PRACTICAL GEOMETRY (*continued*).

FIG. 194.—*To draw a curve which shall be a portion of a circle, when the centre is not available.*

Let A B be the *chord* of the arc, and D C its *rise*.

From A and B as centres, with the radius A B, describe the arcs A E and B F.

From A draw a line through C, cutting the arc B F in G.

From B draw a line through C, cutting the arc A E in H.

Divide A H and B G into any number of equal parts, as, 1, 2, 3, 4, 5, and set off a number of these parts from G and H, as *a*, *b*, *c*, *d*, *e*.

Draw lines from A to 1, 2, 3, 4, 5, and from B to *a*, *b*, *c*, *d*, *e*.

Then it will be seen that the first line above H—viz., *a*—intersects the first line below G—viz., 1—in the point *x*.

In the same manner line 2 will intersect *b*, line 3 will intersect *c*, and lines 4 and 5 will cut *d* and *e*.

Proceed in the same manner on the opposite side, and through the intersections trace the curve by hand.

For inking, a "templet" may be made; and as this plan will be recommended in several other cases, the mode of making this useful article is given.

Draw the figure accurately on a smooth piece of veneer or other thin wood; if of a light colour, so much the better; or a small quantity of veneer may be kept by you, with thin white paper glued over it.

Cut out the form *near* to the line required, and bring it exactly up to the mark by means of a fine file: a half-round file is best for this, as it enables you to finish up concave as well as convex curves. The final smoothing is then to be done with very fine glass-paper, and in this process the edges should be slightly bevelled off (as already advised in the case of set-squares), in order to prevent the ink dragging on the paper.

Sets of curves of different radii and "French curves" of various forms may be purchased, and though these will be found very useful in their way, the above hints are given, as it is deemed advisable to promote self-help as much as possible.

The student will remember that no portion of a true ellipse is a part of a circle, and the curve cannot, therefore, be drawn with compasses so as to be mathematically correct; but there are many ways in which figures nearly approximating to ellipses may be drawn by arcs of circles, which are very useful for general practical purposes. In mechanical drawing, therefore, figures approximating to ellipses are used, and have the advantage that they can be drawn by means of compasses instead of by hand. The following method is given in addition to those which will be found in "Practical Geometry applied to Linear Drawing."

To construct an elliptical figure by means of arcs of circles (Fig. 195).

Place the two diameters A B and C D at right angles, and intersecting each other at their middle point, E.

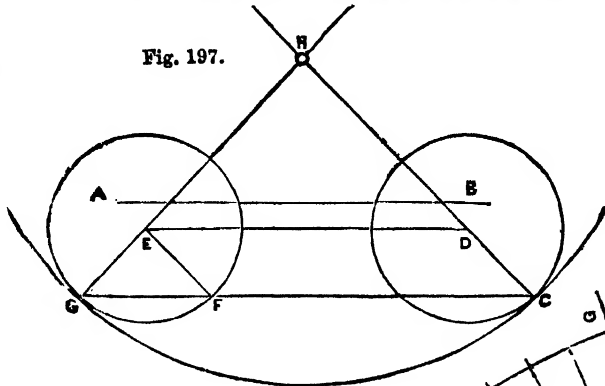
From B on the line A B set off B F equal to E C. From E on E C set off E G equal to E F. Draw G F, and bisect it in I. From F set off F J equal to F I. Draw J K parallel to G F. From E set off E L and E M equal to E J.

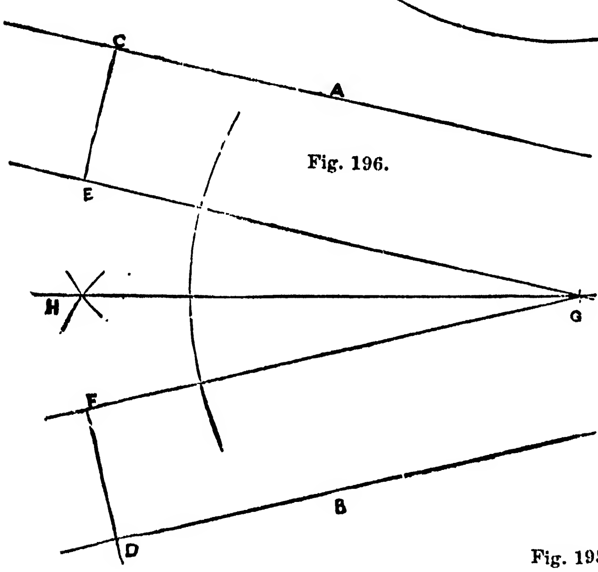
Complete the square J K L M, and produce the sides beyond J and L. The angles of the square are the centres from which the elliptical figure may be drawn.

From K and M, with radius K D or M C, describe arcs cutting the produced sides of the square in N, O and P, Q.

From J and L, with radius L A or J B, describe arcs joining N P and O Q, which will complete the figure.

Fig. 196.—*To bisect the space contained between two lines,* A *and* B, *inclined to each other when the point at which they would meet is inaccessible.*





At any part of each line erect equal perpendiculars, as C E and D F, and from their extremities draw lines parallel to A and B, intersecting in G.

Bisect the angle E G F, and the line G H will bisect the space contained between the lines A and B.

Fig. 197.—*To describe a circle touching two given circles,* A *and* B, *and one of them in a given point of contact,* C.

Join the centres D and E.

Draw a line from C, passing through D, and produce it.

At E draw E F parallel to D C.

Draw C F parallel to E D, and produce it to G.

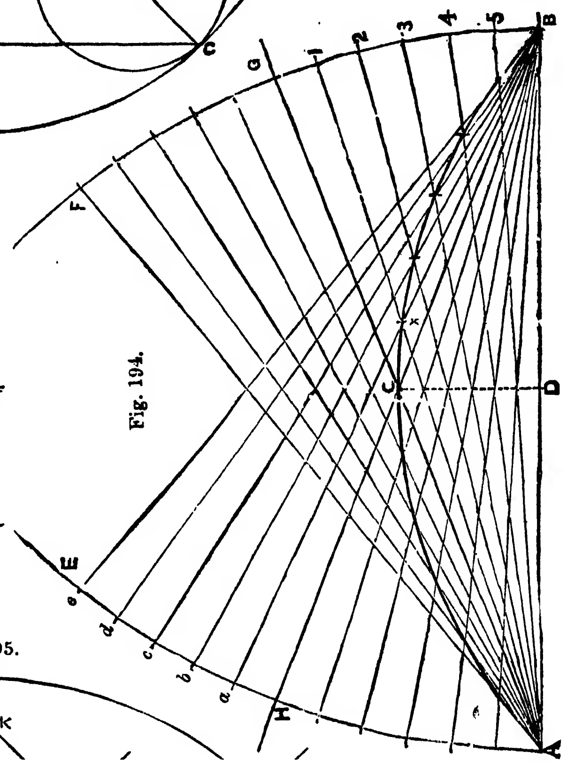
Draw G E, and produce it until it intersects C D produced in H.

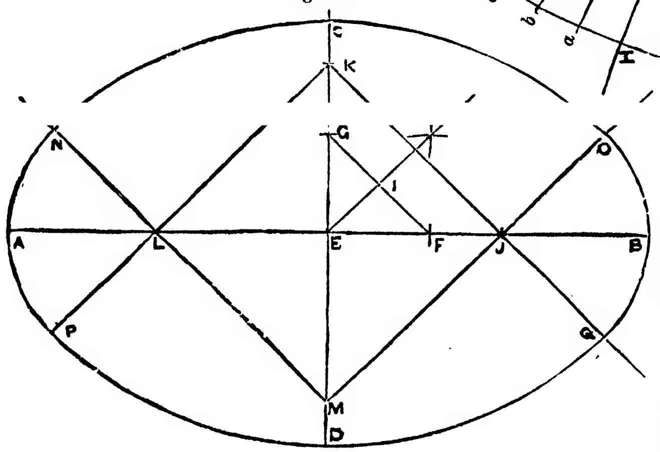
From H, with radius H C, describe the required circle, which will touch both the circles A and B, and one of them in the given point C.

Fig. 198.—*To divide a circle into any number of equal parts.*

The following constructions, which require the compasses alone, are best made with the steel dividers, and if two or three pairs can be employed, the distances (such as the radius of the circle), often required, can be kept unaltered.

With the given radius describe the circle, and divide it into *six* parts in B, C, D, E, F, G. B E is a diameter, and therefore divides it into *two*. B D is the chord of $\frac{2}{6}$ or $\frac{1}{3}$, and the circle is





divided in B, D, F into *three* parts.

From each end of the diameter B E, with the chord of B D or C E, describe arcs intersecting in X.* Then the distance A X being set off from B and E, the circumference will be divided into *four* parts in H, B, I, E.

The arc described with the radius A B from X, X as centres will cut the circumference in K, L, M, and N, which points bisect the quadrants B H, H E, E I, and I B, and thus divide the circle into *eight* equal parts.

The radius A B, set off from H, I to O, P, Q, R, bisects the arcs

* In all these constructions, in order to ensure greater accuracy, the arcs should be described on both sides of the line joining the centres; thus the point X should be found on both sides of the diameter B E.

B C, D E, E F, and G B, which completes the trisection of each quadrant, and therefore divides the circle into *twelve* parts.

The radius A B, set off from K, L, M, and N, both ways from each point, will bisect the two arcs on each side of the extremities of the diameters, B E, I H in S, Y, U, V, W, Z, *a*, *b*, and thus complete the division of the circle into *twenty-four* parts.

Any further subdivision may either be done by bisecting the arcs already formed, or by trial. Thus each of the twenty-four parts being bisected, the circle will be divided into *forty-eight* parts.

All the foregoing constructions, by which the circumference is divided into twenty-four parts, are performed, it will be seen, *by three distances only*, the radius A B, the chord B D, and A X; consequently, if these be kept unaltered in separate pairs of dividers, the operations are performed with the greatest accuracy.

In order to avoid confusion, the continuation of this problem is given in a separate figure (Fig. 199). With the distance A X as a radius, from O, P, Q, R (these points having been found as in the last figure), describe arcs intersecting in Y; then the distance B Y, or E Y, will divide the circumference into *five* equal parts in B, C, D, F, and G. The distance A Y will bisect the arcs B C, C D, D F, etc., in H, I, E, K, L, and thus divide the circle into *ten* parts.

The distance B Y, set off from S, T, the extremities of the diameter S T, perpendicular to B E, will bisect the arcs D E, B H, E F, B L in the points U, V, W, Z, and will thus give *one-twentieth* of the circumference. The same distance being set off from these points will bisect the other arcs of the decagon.

The division into *forty* parts may be effected by bisecting the arcs last found.

These constructions will be found useful in drawing regular polygons, and in dividing the circles for toothed wheels. Of course no more of the figure need be worked than is necessary for the immediate purpose.

Fig. 200.—*To join two lines,* A B, *inclined to each other, by an arc of a circle.*

Produce A and B until they meet in C.

Bisect the angle A C B.

At D, the extremity of one of the lines, erect a perpendicular, cutting the line of bisection in E. From E, with radius E D, describe the arc D F which will meet A in F.

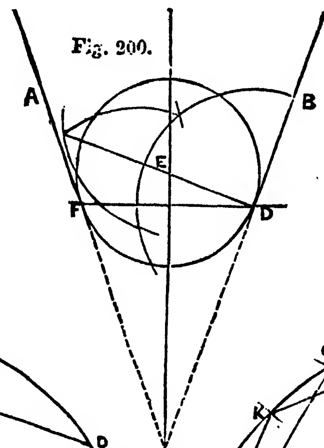


Fig. 200.

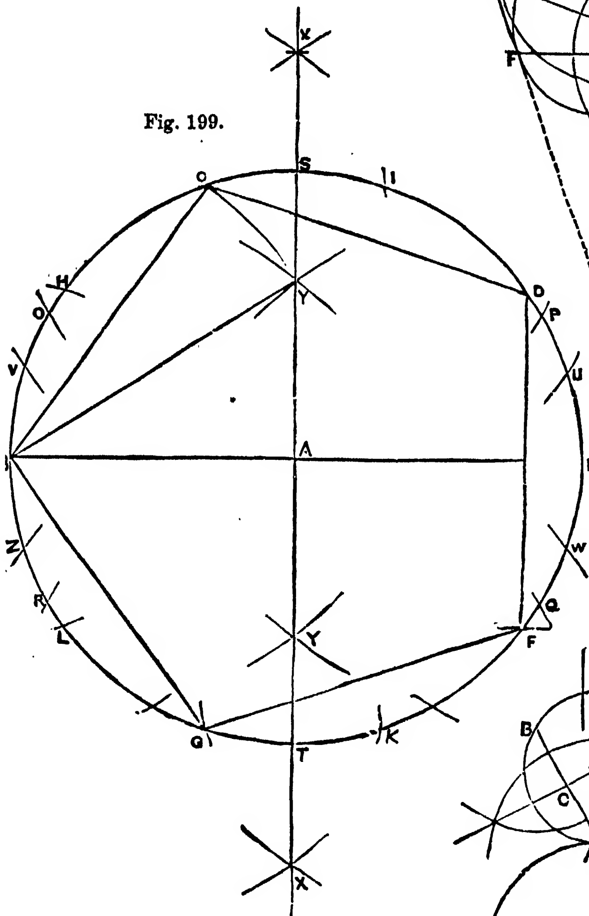


Fig. 199.

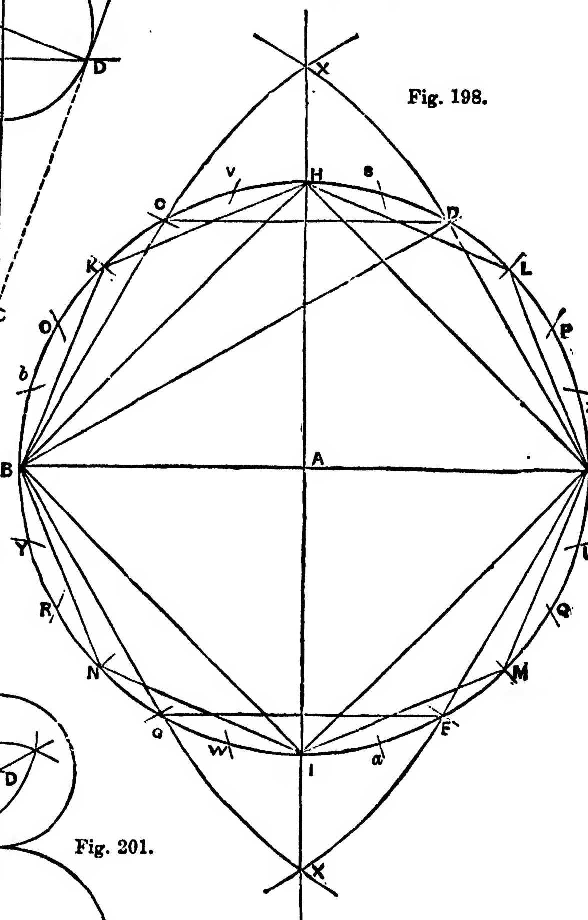


Fig. 198.

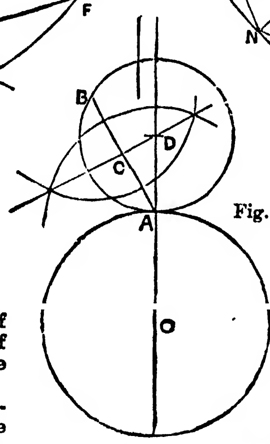


Fig. 201.

If the point C is not accessible, the angle must be bisected as shown in Fig. 196 in the preceding page. This method of bisecting an angle should be carefully practised by the learner.

Fig. 201.—*To draw a circle touching another circle in a given point, and passing through a given point lying without the circle.*

Let A be the point of contact in the given circle, and B the point lying without it.

The centre of the required circle will evidently lie on the radius O A produced, and on a perpendicular at the middle of a line joining A B, which line will be a chord of the required circle; therefore

Produce O A to as great a length as may be necessary.

Draw a line from A to B, and bisect it in C.

Produce the bisecting line until it cuts O A produced in D. The point D is the centre of the required circle, D A being the

PROJECTION.—XII.

QUESTIONS FOR EXAMINATION.

The following questions, selected for the most part from the papers given at the Government and other examinations, are appended with the view of enabling the student to test his own knowledge, and as suggestions to teachers as to the mode of stating problems on this subject. It is hoped that the examples already given, and the application of them, will have shown the constructions upon which all the questions are based.

1. Give the plan and elevation of a line 3 inches long, when parallel to the vertical and horizontal plane, and 2 inches distant from each.

2. Give the plan and elevation of this line when it is at right angles to the vertical and parallel to the horizontal plane, its height being 2 inches from the ground.

3. Give the plan and elevation of the same line, when the former is a point, and the latter a vertical line 3 inches long.

4. Give the elevation and plan of the same line when it is parallel to the vertical, but is inclined to the horizontal plane at 70°.

5. Give the plan and elevation of the line, when it is inclined at 70° to the horizontal, and 45° to the vertical plane.

6. A wire 3 inches long projects from a wall at 60° to the surface, and is parallel to the ground. Give the plan and elevation.

7. A plane 2″ × 3″ rests on its narrow edge in such a manner that its surface is at right angles to both planes. Give plan and elevation.

8. Give plan and elevation of the same plane, when its surface is vertical, but inclined to the vertical plane at 45°.

9. Give plan and elevation of the same plane when its shorter edges are at right angles to the vertical plane, and its surface inclined to the horizontal plane at 60°.

10. Give plan and elevation when the plane rests on one of its short edges, its surface being inclined at 60° to the horizontal plane, and its long edges being at 45° to the vertical plane.

11. A square plane of 3 inches side lies on the horizontal plane, its one diagonal being at right angles to the vertical plane, and the other parallel to it. Give plan and elevation.

12. Give elevation and plan when the plane rests on one of its angles, its surface being inclined at 40° to the horizontal plane, but its one diagonal remaining at 90° to the vertical plane.

13. Give plan and elevation of the same plane when one of its diagonals is at 45° to the horizontal, and 60° to the vertical plane, the other diagonal being parallel to the horizontal plane.

14. A cube of 2 inches side stands on the horizontal plane, with two of its faces parallel to the vertical plane. Give its plan and elevation.

15. Draw its plan and elevation when standing on one of its sides, the opposite one being horizontal, and the others being at 45° to the vertical plane.

16. Give plan and elevation when resting on one of its solid angles, one diagonal of the base being at 50° to the horizontal, and the other at 90° to the vertical plane.

17. Draw elevation and plan of the same cube, when resting on one of its *edges*, so that two of its sides are vertical and the rest make angles of 45° with the horizontal, but are at right angles to the vertical plane.

18. Add the shape (the *development*) of the piece of metal or other substance which on being folded would form the above-named cube.

19. There is a stick of timber 2 inches square at base, and 5 inches high. Give the true shape of a section caused by a plane entering at one angle of the top, and emerging at the opposite angle of the base.

20. Give the development of one portion of this square prism when it has been cut as in the last question.

21. Give plan and elevation of a triangular prism when resting on one of its long faces, the surface of the triangular end being at 50° to the vertical plane. The end is an equilateral triangle of 2 inch edge, and the length of the prism is 3½ inches.

22. Give plan and elevation of the same prism when the edge of the end on which it rests is at 50° to the vertical plane, and the under side is inclined to the horizontal plane at 35°.

23. Add the development of this prism.

24. Draw the plan and elevation of a regular pentagon of 1 inch side when resting on one of its angles, so that its surface is at right angles to the vertical, and at 60° to the horizontal plane.

25. Give the projection of this polygon when the line joining the angle on which it rests to the middle of the opposite side is at 40° to the vertical plane, the inclination to the horizontal plane remaining the same as in the last figure.

26. There is a hexagonal prism of 1 inch side and 4 inches long. Draw plan and elevation when standing on its end, with two of its faces parallel to the vertical plane.

27. Give the plan and elevation of the same prism, when the axis is vertical and one of its faces is at 40° to the vertical plane.

28. Give elevation and plan of the same prism when two of its faces are parallel to the vertical plane, and the prism is so inclined that the axis is at 50° to the horizontal plane.

29. Draw the plan and elevation when the prism rests on one of the solid angles, and the axis is at 50° to the horizontal, and 45° to the vertical plane.

30. Project the prism when lying on one of its long faces, the axis being at 40° to the vertical plane.

31. Give the true section caused by a plane passing from one angle of the top to the opposite angle of the bottom.

32. Draw the development of the prism, marking on it the line of section, as per last figure.

33. There is a prism, the ends of which are regular octagons of ¾ inch side, and the sides of which are 4 inches long. Give the plan and elevation of this object when the one edge of the base rests on the ground, and the corresponding edge of the top touches the edge of a cube of 2 inches side.

34. Give the plan and elevation of this group when rotated so that the sides of the cube are at 45° to the vertical plane.

35. Project the front view of an octagonal prism (size at pleasure), when its end rests in a plane inclined at 35°, neither of the long faces being parallel to the vertical plane.

36. Give a section of the prism named in Question 33, caused by a plane passing through it at 60° to the axis; the prism to be hollow, and formed of wood ½ inch thick.

37. Give plan and elevation of a hexagonal pyramid when two of the edges of the base (1 inch long) are at 20° to the vertical plane, the altitude being 2½ inches.

38. Draw elevation and plan of this pyramid when lying on one of its triangular faces, with its axis parallel to the vertical plane.

39. Give the elevation and plan of this pyramid when resting on one angle of the base, and one of its edges being vertical.

40. A circular disc (1½ radius) stands so that one diameter is vertical, and another at right angles to the first is at 50° to the vertical plane. Give plan and elevation.

41. Give elevation and plan of the same circular disc, when resting on the end of one diameter, which is parallel to the vertical plane, the surface being at 40° to the horizontal plane.

42. Draw the plan and elevation of the same disc, when the diameter is at 40° to the horizontal and 60° to the vertical plane.

43. A circular slab of stone, such as a mill-stone, 4 feet diameter and 1 foot high (*to be represented by inches for feet*), lies on the horizontal plane. Give the plan and elevation.

44. A second circular slab, 3 feet diameter, and 1 foot high, rests on a slab, similar to the last; their centres being coincident. Draw the plan and elevation.

45. Draw the elevation, plan, and projection of these two slabs, one placed on the other, as above, when their circular surfaces are inclined at 40° to the horizontal plane.

46. A cylinder, 4 inches long and 2 inches diameter, stands on its circular end. Give the plan and elevation.

47. Draw the plan and elevation of the same cylinder when lying on the horizontal plane, its axis being parallel to both planes of projection.

48. Give plan and elevation of the cylinder when lying on the horizontal plane, its axis being at 60° to the vertical plane.

49. Draw the plan and elevation of a cylinder 4 inches long and 2 inches diameter, when the axis is inclined at 60° to the horizontal and 45° to the vertical plane.

50. Give the true section caused by a plane passing through the middle point of the axis at 45° to it.

51. Draw the development of this cylinder, marking on it the line of section.

52. A cylindrical pipe, of 2 inches diameter, is to be cut so as to turn a right angle. Give plan and elevation, showing the section-line.

53. Give the elevation and plan of one of the parts when resting on the sectional surface.

54. Give the true shape of the section, and the development, showing how both parts of the elbow may be cut out of the same piece of metal without any waste.

55. From piping of the same diameter, construct a double elbow-joint, one end of which bends one way and the other the opposite. Give development of the three parts to be cut out of one piece without waste.

56. The same piping is to be carried round three sides of a square room (size at pleasure). Give development, showing the section-line.

57. A pipe of sheet iron (2 inches diameter) is to be joined so as to turn an angle of 120°. Show on an elevation the inclination of the line of section, and show on a development the line in which the metal must be cut to form the required parts without any waste.

58. Given a cone of 2½ inches base and 3½ inches altitude. Draw the plan and elevation of this cone when standing on its base.

59. Give elevation and plan, when the cone lies on the horizontal plane, its axis being parallel to the vertical plane.

60. Draw the projection of the cone, when lying on the horizontal, with its axis at 45° to the vertical plane.

61. Project the cone when resting on one end of the diameter of the base, the axis being inclined at 70° to the horizontal plane.

62. Project the cone, when the axis is inclined at 70° to the horizontal and 45° to the vertical plane.

63. Draw the true section of the same cone caused by a plane at 40° to the surface of the base, which enters at ½ inch from the bottom.

64. Draw the parabola resulting from a plane entering the base of a similar cone at ¾ inch from the centre.

65. Draw the hyperbola resulting from a section-plane entering the base of a similar cone at ¾ inch from the axis.

66. A pipe 2 inches square is penetrated by another of 1 inch side. The smaller one passes through 2 sides of the larger, their axes being at right angles to each other. Give elevation and plan when two faces of each of the pipes are parallel to the vertical plane.

67. Project this object when the two faces, which in the last case were parallel to the vertical plane, are at 60° to it.

68. Give the development of the larger pipe, showing the exact shape of the aperture through which the smaller one is to pass.

69. Give the elevation and plan of the object when the smaller pipe penetrates the sides of the larger at 60°.

70. Draw the development of the larger pipe, showing the apertures, and of one piece of the smaller one.

71. A square pipe of 2 inches side is penetrated by another of 1½ inch side, their axes being at 60° to each other, and parallel to the vertical plane; and two *edges* of the smaller meeting two edges of the larger pipe. Give the elevation and plan.

72. Draw the plan and elevation, when two faces of the larger pipe are parallel to the vertical plane.

73. Draw the development of the larger pipe, showing the shape of the apertures through which the smaller one is to pass, and also one of the ends of the smaller pipe.

74. A cube of 3 inches side stands on the horizontal plane, and is surmounted by a square pyramid, 3 inches high. Give elevation and plan, when two faces of the cube and two of the sides of the base of the pyramid are parallel to the vertical plane.

75. Draw the elevation and plan of this object, when the faces are parallel to the vertical plane, as in the last question, but when the base is inclined at 25° to the horizontal plane.

76. Draw the plan and elevation of the object, when the sides of the cube are at 50° and 40° to the vertical plane.

77. Give plan and elevation of the object, when the faces of the cube are at 45°, and two of the sides of the base of the pyramid are parallel to the vertical plane, their axes being coincident.

78. Draw the shape of the piece of metal to form a gas-shade, 20 inches wide across the circular base, 6 inches across the top, and 10 inches perpendicular height. (To be worked ¼ size.)

79. A cylindrical coal-scuttle is to be made of sheet iron; it is to be 10 inches in diameter and 18 inches high at the highest part, the lid to be inclined at 45°. Draw the shape the metal is to be cut to form this object, and the exact shape of the lid. (To be worked ¼ size.)

80. A cylinder, 2½ inches diameter and 6 inches long, is penetrated by another of 1½ inch diameter and 5 inches long, their axes being at right angles to each other, and intersecting at their centres. Show the mode of obtaining the curves of penetration. Develop the larger cylinder and one of the ends of the smaller one.

81. Draw the plan and elevation of this object when the axis of the larger is parallel, and of the smaller at 60° to the vertical plane.

THE STEAM-ENGINE.—IV.

By J. M. Wigner, B.A., B.Sc.

BOILERS (*concluded*)—THE FURNACE—RELATIVE VALUE OF DIFFERENT KINDS OF COAL—DRAUGHT—SMOKE-CONSUMING ARRANGEMENTS—TEMPERATURE AND PRESSURE.

We have now referred to those forms of boiler which have come into most general use. There are, however, many other varieties, some of which are only available for special and peculiar work, while others are of comparatively recent introduction, and have as yet to stand the test of experience. Sectional wrought-iron boilers have been tried of late years, with apparently good results. In these the water is contained in wrought-iron tubes of comparatively small diameter, round which the flame and heated gases are made to play. These tubes are proved to a great pressure before being used, and are so arranged that if by accident any one should become injured or ruptured it can easily be either cut out of communication with the rest of the boiler, or removed and replaced by a fresh one. In one form of boiler, on this principle, a number of parallel wrought-iron tubes are placed above the furnace, from each of which a small tube leads into the general steam-pipe. In other forms, the tubes are connected to one another at the ends, but the connections are so arranged that any defective one can easily be separated from the rest. Many advantages are claimed by the manufacturers of these boilers, among which are economy in use and greatly-increased safety—an injury being easily discovered and repaired, and an explosion of the whole being rendered almost impossible.

One of the uses to which the steam-engine has been applied is to work a fire-engine. In large towns, where dwellings and warehouses are closely packed, fires spread very rapidly, and manual engines are found not to be sufficiently powerful to extinguish them with promptitude. Steam is therefore employed; but in this case the desideratum is an engine and boiler so constructed as to get up steam in a very short time, as otherwise the fire gains a very powerful hold before the engine can be set to work. Much attention has accordingly been directed to this point, and with such success that engines are now made capable of throwing very large jets of water within a few minutes of the time when their fires are lighted. The boilers usually employed are of very small dimensions, and contain a large number of short tubes very closely packed; quick-burning fuel is also employed, so that a powerful draught is at once produced. The quantity of water in the boiler is of course very small, and thus a high pressure is quickly attained. The engine is so arranged that at every stroke a small quantity of water is injected into the boiler, sufficient to take the place of that converted into steam, without materially reducing the temperature of the rest. The amount of work accomplished by these engines is very great indeed, when considered with reference to their size and weight. They are usually worked at great speed, and with steam at a pressure of from 100 to 150 pounds to the inch. In an official trial of fire-engines at the International Exhibition of 1862, steam was got up to a pressure of 100 pounds by two different engines in 12 minutes 10 seconds and 18½ minutes respectively, from the time of lighting the fires, the boiler in each case being filled with cold water at starting. Sometimes these engines are made to propel themselves along

the road to the fire, but this plan is not generally adopted, as it is found better to start at once with horses, and get up steam while going along. One drawback to the use of boilers of this kind, with the tubes so closely placed, is that they soon become incrusted, and the fur deposited hinders the circulation of the water. As, however, fire-engines are not very often set to work, and then only for a comparatively short period, there is plenty of time for removing this accumulation, and the boiler is so constructed that the covering can easily be removed and the tubes laid bare for this purpose.

We must now pass from the details of the boiler to notice the arrangements of the furnace, many of which have already been referred to in connection with the boilers of which we have spoken.

The furnace is the source of all the power. The fuel supplied to it enters into chemical combination with the oxygen of the air, evolving thereby a large amount of heat, which, by the medium of the steam, becomes in time converted into force. The fuel usually employed is coal—a mineral substance consisting principally of carbon and hydrogen, together with some sulphur and various incombustible mineral ingredients which remain behind in the form of ash. During the process of combustion, the carbon, hydrogen, and sulphur unite with the oxygen of the air, producing various gaseous products, the principal of which are carbonic oxide, carbonic acid, and watery vapour. The exact products vary with the coal employed, different samples of which are found to differ very greatly in their composition, and accordingly in the duty they are capable of performing. Good coal ought to contain at least three-fourths its weight of carbon—often it contains considerably more.

It will easily be seen that the amount of heat produced by the consumption of a given weight of coal is a very important point in connection with the economical employment of the engine. A large number of experiments have therefore been tried with coal of every variety. A very important series of trials of this kind, conducted under Government authority at Woolwich, was brought to a close a few years ago, and the results published as a Parliamentary paper which is well worthy the attention of all employers of steam-power. These trials had extended over many years, and were carried on with great care. Boilers were fed with water at a uniform temperature of 100°: the trial was then continued some days, the exact amount of coal consumed being noted, and also the amount of water evaporated. It would be impossible here to insert even a general abstract of those trials, but the following extracts will give an idea of the average duty which should, under favourable circumstances, be obtained :—

Description of Coal.	Pounds of Water evaporated for each pound of Coal consumed.
Best Welsh Coal	9·493
Anthracite	9·014
Best Small Newcastle Coal. .	
Average Small Newcastle Coal	8·074
Average Welsh Coal	8·045
Large Newcastle Coal . . .	7·658
Derbyshire	6·772

Generally, then, we may state that from 7 to 9 pounds of water at 100° (which may be taken as the average temperature of feed-water) should be evaporated by each pound of coal consumed in the furnace. The best results are those obtained with a Cornish boiler, that being the form of boiler in which the greatest economy of fuel is obtained. This economy has been partly produced by the system, which has long prevailed in that district, of publishing the results obtained as compared with the coal used. This plan has produced a kind of competition that has acted very favourably. In many cases little care is taken as to the construction or management of the furnace, and the results then obtained are, of course, much inferior to those given above.

By inquiring a little into the process of combustion that goes on in the furnace we shall be able to understand more clearly the different things requisite in order to ensure perfect combustion. Carbon itself burns almost without flame when heated to a temperature of 700° or 800°. The hydrogen in the coal is for the most part combined with some of the carbon, producing the gas known as carburetted hydrogen, and thus it is which produces the flame and smoke. The products of combustion are themselves invisible, but this gas carries with it small particles of the coal mechanically suspended, and, if not perfectly consumed, deposits, in addition, a portion of its carbon in the form of dark smoke.

All smoke that escapes will thus be seen to be a loss of so much fuel, and therefore, apart from the nuisance, motives of economy point to the need of fully consuming the smoke produced in any furnace.

To perfectly consume a pound of carbon requires 12 cubic feet of oxygen gas. In the air, however, this gas is diluted with four times its bulk of nitrogen; 60 cubic feet of air are therefore required to consume 1 lb. of carbon. It is not, however, to be supposed that all the oxygen is extracted from the air as it passes through the furnace: only a portion is removed, and the rest escapes up the chimney, with the products of combustion. We may, therefore, assume that about 150 cubic feet of air should pass into the furnace for each pound of coal consumed, the exact quantity varying considerably with the shape and construction of the furnace. If too little is admitted, combustion will be imperfectly carried on, and much smoke will accordingly be produced, while the heat obtained will be less than that required. On the other hand, too large a supply of cold air will materially reduce the temperature, besides carrying off a large amount of waste heat up the chimney.

The usual manner in which a powerful draught is maintained, so as to ensure a sufficient supply of air, is by means of a tall chimney.

The air having passed through the furnace becomes intensely heated, and accordingly expands. In this way it is rendered much lighter than the air around, and ascends the chimney, while fresh air rushes through the furnace to supply its place. With a stationary furnace sufficient draught can always be obtained in this way, and dampers are introduced into the flues to reduce it when needful. In locomotives, however, where a long chimney is, of course, inadmissible, artificial expedients are employed to quicken the draught.

Under ordinary circumstances, when a fresh supply of fuel is thrown into the furnace, the heat at once drives off a large portion of the carburetted hydrogen, which takes with it minute particles of dust, and the supply of air is for the time insufficient to consume these. Volumes of dense smoke accordingly issue from the chimney, and much attention has been directed to the best mode of avoiding this. Very much depends upon the manner of feeding the furnace. If a large supply of coal is thrown carelessly into it, there is sure to be a large production of smoke. If, on the other hand, the fuel be introduced in frequent small supplies, and placed near the furnace-door, the smoke produced will have to pass over the intensely-heated cinders beyond, and will be entirely consumed; and this is the principle of most of the smoke-consuming arrangements at present in use. The fuel is introduced in small quantities and at frequent intervals, and the smoke is burnt by being compelled to pass over the surface of the highly incandescent fuel already in the furnace.

Another plan by which smoke may also be reduced is by allowing an additional supply of air to enter the furnace and pass into the combustion chamber, where it mingles with the smoke, and aids in its complete combustion.

The former of these plans is by far the most generally adopted, though, of course, there are very many ways in which the principle may be carried into practice. The most important thing of all is to procure a careful and intelligent stoker, for more, as a general rule, depends on this than on the apparatus used. A perfect self-feeding apparatus would be the best preventive of smoke: this, however, has yet to be discovered.

With an ordinary furnace little smoke will be caused if the fire is well managed The fuel, as already stated, should be introduced frequently and in small quantities. Before doing so, the stoker should open the furnace-doors and push back a portion of the fuel, so as to make a space in front for the fresh supply, which should be spread evenly on the fire-bars. It will then first become coked—that is, the gases will be expelled, and, in passing over the rest of the furnace, will be entirely consumed. The coke then burns in a clear, smokeless way.

This plan, however, requires constant care and watchfulness, which it is difficult at all times to ensure.

Some furnaces are constructed with a self-feeding arrangement. The coal employed in these is usually crushed almost to dust, or else small coal is employed. It is introduced into a hopper above the furnace, and a small revolving scoop, driven by the engine, constantly and slowly sprinkles the coal into it. A slow motion is also imparted to the furnace-bars, so that the burning fuel is gradually carried to the back of the furnace as fresh coal or coal-dust is supplied in front.

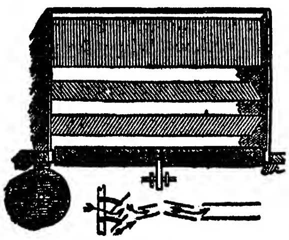


Fig. 19.

The main drawbacks to this system are the somewhat complicated nature of the mechanism and the power required to drive it, but, despite these, it is found in many places to answer very well, and to effect a saving in cost of fuel. The supply of coal is rendered quite uniform, and all the smoke is consumed. Sometimes the furnace-bars are laid transversely and connected to the links of an endless chain, and then made to travel slowly along. In other forms they are longitudinal, and an oscillating movement is given to the alternate ones at the end nearest the furnace-door, so that the same effect is produced—the coal being slowly moved back in the furnace, and the ashes discharged at the further end.

Frequently two furnaces are employed, being placed side by side, and alternately fed. These are so arranged that the smoke from the one passes through the other, and is consumed. But we cannot stay even to enumerate the different plans of smoke-consuming apparatus that have been tried. There is, however, one very ingenious and useful contrivance to which we must just refer. It is known as "Prideaux's Self-closing Furnace Valve," and serves to regulate the supply of air admitted to the furnace. The apparatus, which is fitted as a door to the furnace, consists of three series of vertical plates, placed behind one another, as shown in plan in Fig. 19. The two outer sets are a little inclined in opposite directions, so as to prevent any loss of heat by radiation. The air as it enters the furnace passes between these plates, and thus keeps the outer portion of them cool, while it becomes itself raised to a very high temperature, and thus aids more perfectly in carrying on combustion. In front of these partitions is a series of horizontal shutters, mounted so as to close somewhat after the manner of Venetian blinds (Fig. 20). A weight, *c*, fixed at the end of a lever, *a*, closes these. This weight is, however, prevented from falling rapidly by means of the cylinder, *b*, containing water. A piston works in this cylinder, and is so arranged that it can readily rise to the top, the water in the cylinder passing below it. There is, however, only a very small return channel for the water, the size of which can be regulated by a set-screw. The piston, therefore, can only fall very slowly, and as the weight *c* is connected to it, the shutters likewise close very slowly and gradually. Usually the apparatus is so adjusted that it shall take seven or eight minutes for the piston to fall.

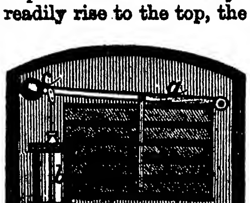


Fig. 20.

When the furnace-door is opened to introduce fresh fuel the piston is raised to the top, and the shutters are accordingly opened and admit a plentiful supply of air, which becomes heated on its way, and aids in consuming the smoke produced. As the fuel becomes coked less air is required, and the shutters gradually close, diminishing the supply. In this way the supply of air is nicely adjusted to meet the requirements of the furnace, while at the same time the air that enters is warmed, and consequently does not reduce the temperature as it otherwise would.

Other arrangements have been suggested for the purpose of warming the air by means of the waste heat, ere it is allowed to enter the furnace, but these have not been at all generally adopted.

The student will now have acquired a general acquaintance with the details of construction of the boiler and its appendages, and we can, therefore, pass on to inquire into the mechanism of the engine itself, and the different forms given to it. Before doing so, however, it will be useful to append a table, showing the temperature of steam at any given pressure. Under the ordinary pressure of the air water boils at 212°, and the temperature of the steam never exceeds this. When, however, we have a closed vessel like a boiler, and allow the pressure to become greater than that of the air, we find the temperature rises, and the ratio of this increase will at once be seen by reference to the table.

Temperature.	Pressure.		Temperature.	Pressure.	
	Atmospheres.	Pounds.		Atmospheres.	Pounds.
212°	1	15	293·7	4	60
234		22½	307·5	5	75
250·5	2	30	320·4	6	90
263·8		37½	358·9	10	150
285	3	45	418·5	20	300

ELECTRICAL ENGINEERING.—X.

BY EDWARD A. O'KEEFFE, B.E., A.S.T.E.,

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PRIMARY BATTERIES.

CLASS III.—LECLANCHÉ CELL (*continued*).

THE Leclanché cell is so extensively used for the purpose of supplying the energy necessary to ring bells, and electric bells have come into such general use, that it may be advisable to dwell longer on this cell than its importance from a scientific point of view might seem to warrant.

The aliment is a strong solution of sal ammoniac, or chloride of ammonium, which is a compound of nitrogen, hydrogen, and chlorine. The chlorine unites with the zinc and forms chloride of zinc, while the nitrogen and hydrogen unite with the oxygen given off from the manganese dioxide to form ammonia and water. As long as this action continues in the cell, polarisation is prevented, and the E.M.F. is not lowered; but as the oxygen is only slowly given off from the manganese dioxide, the hydrogen ultimately is deposited on the carbon, and polarisation begins. The manganese dioxide (MnO_2), on parting with a portion of its oxygen, becomes reduced to manganese sesquioxide (Mn_2O_3).

The chemical reaction may be thus expressed:—

Before passing the current:

$$\underset{\textit{Zinc}}{Zn} + \underset{\textit{Sal ammoniac}}{2(NH_4Cl)} \;\Big|\; \underset{\textit{Manganese dioxide}}{2(MnO_2)} + \underset{\textit{Carbon}}{C}$$

After passing the current:

$$\underset{\textit{Chloride of zinc}}{ZnCl_2} + \underset{\textit{Ammonia}}{2(NH_3)} + \underset{\textit{Water}}{H_2O} \;\Big|\; \underset{\textit{Manganese sesquioxide}}{Mn_2O_3} + \underset{\textit{Carbon}}{C}$$

Or it may be expressed in words by saying that zinc unites with sal ammoniac to form chloride of zinc, and ammonium is set free; this ammonium unites with the oxygen of the manganese dioxide to form ammonia and water; the manganese dioxide is reduced to manganese sesquioxide, and the carbon plate remains in its original state, free from hydrogen.

If the original solution of sal ammoniac be not sufficiently strong, insoluble oxide of zinc is formed instead of chloride of zinc, and the solution assumes a chalky appearance, but this may be prevented by adding some sal ammoniac to the solution. When this cell is supplying a current, ammonia is given off from it, which attacks and corrodes the connecting wires if they are left unprotected. In order to avoid this they must be covered with tar, gutta-percha, Chatterton's compound, or some such substance.

Chatterton's compound is so extensively used in all electrical work that it may be well to mention its composition, which is as follows:—

Gutta-percha - -		
Resin - - - -	1	} By weight.
Stockholm tar - -		

In order to make connection with the carbon plate, a lead cap, into which a brass terminal can be screwed, is used. The upper portion of the carbon plate is first placed in paraffin wax at a temperature of 110° C.; a couple of holes are then drilled through it, and the lead cast on in the shape shown in Fig. 18, p. 218. If the carbon had not been soaked in paraffin, lead salts would form at the junction of the lead and carbon, which would at first introduce a high resistance, and finally destroy the connection between the terminal and the carbon.

There is scarcely any waste of materials in this cell when it is not in actual use.

BICHROMATE CELL.

This cell is usually made up as shown in Fig. 20. K K are two carbon plates which form the negative element, and are in metallic connection with one of the brass binding screws on the ebonite cap of the glass flask. Z is a zinc plate forming the positive element, and is attached to a brass rod, *a*, which can slide up and down through a brass collar, so that the zinc plate can be withdrawn from the liquid when desired. The solution is made of bichromate of potash, sulphuric acid, and water, in the following proportions:—

Fig. 20.—THE BOTTLE BICHROMATE.

Bichromate of potash	1	By weight.
Concentrated sulphuric acid	2	
Water	12	

The bichromate of potash is in the form of crystals, which should be powdered and gradually added to the sulphuric acid, and well stirred. This mixture should be allowed to rest for some time, and the water then added. The addition of the water heats the mixture, and the operation should be conducted slowly. When the solution has become quite cold it may be placed in the flask, and the cell will then be ready for use.

The chemical reaction which then takes place can be thus expressed:—

Before passing the current:

$$\underset{\textit{Zinc}}{3Zn} + \underset{\textit{Sulphuric acid}}{6H_2SO_4} + \underset{\textit{Chromic acid}}{2CrO_3} + \underset{\textit{Carbon}}{C}$$

After passing the current:

$$\underset{\textit{Sulphate of zinc}}{3ZnSO_4} + \underset{\textit{Water}}{6H_2O} + \underset{\textit{Chromium sulphate}}{Cr_23(SO_4)} + \underset{\textit{Carbon}}{C}$$

When this cell is required for use and the zinc lowered nto the solution, the above-described action takes place; but even when a current is not being drawn from it, the zinc is violently attacked by the chromic acid and quickly burnt away. To prevent this action, the zinc must be raised out of the liquid when the cell is not in use. This cell has a high E.M.F.—about 2 volts—and an extremely low internal resistance; the consequence being that it can supply a strong current, but only for a short time. If allowed to rest for a few minutes it quickly recovers itself, and is as good as before. It gives off no noxious fumes, and is very compact; and though it is admirably adapted for some special kinds of work, such as giving a strong current for a short time for medical purposes, it possesses the one fatal fault that the zinc cannot be allowed to rest in the solution when not in action, and this fault practically disqualifies it from coming into general use.

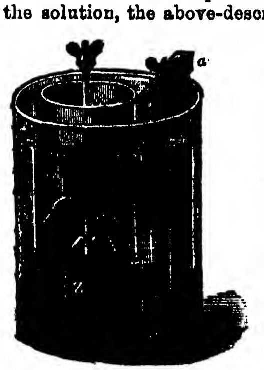


Fig. 21.—FULLER'S BICHROMATE CELL.

A modification of this cell, due to Fuller, is free from the fault just described, and is largely used both in telegraphy and in general electrical work. Fig. 21 shows one form in which it is made up.

The constituents and chemical reactions are the same as in the bottle type, but the form of cell is different. The outer vessel contains the carbon plate, *a*, and the bichromate solution; the porous pot contains the zinc, Z, immersed in water or in very dilute sulphuric acid. A little mercury is also added, so as to keep the zinc thoroughly and permanently amalgamated. Its E.M.F. is the same as that of the bottle type, but its resistance is much higher. It does not readily become polarised, and the zinc, not being in contact with the bichromate solution, can remain in the cell without injury for a considerable time. The solution is of a rich orange colour, and as long as it retains this colour it is in good condition, but as soon as it begins to assume a bluish tint the bichromate is becoming exhausted. When this occurs the solution must either be changed, or a portion of it withdrawn and a fresh supply of the above-mentioned constituents added.

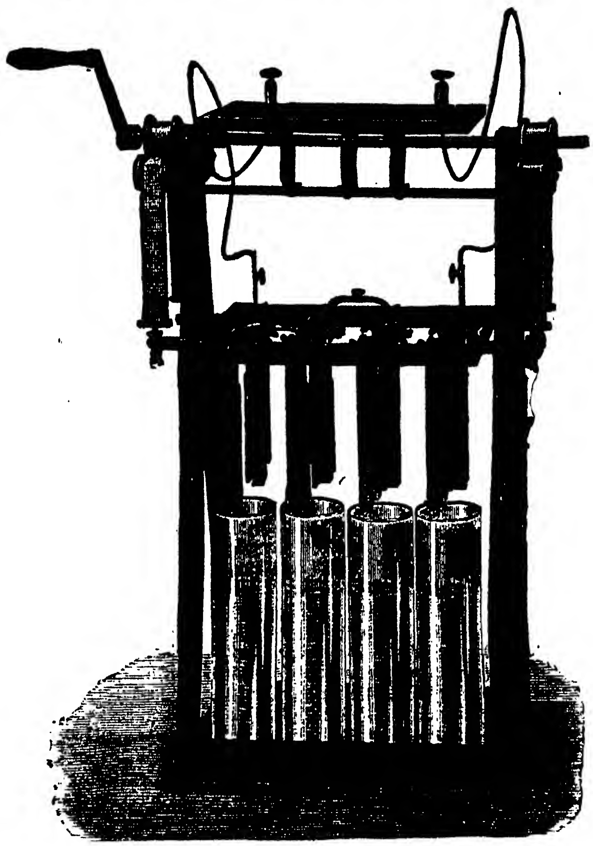


Fig. 22.—BUNSEN'S BICHROMATE BATTERY.

Where a powerful current for only a short time is required, Bunsen's bichromate battery is very convenient.

It consists of a number of cells of the bottle type, with a convenient arrangement for raising and lowering the elements. The details of construction can be clearly seen from Fig. 22. It possesses all the advantages, as well as the disadvantages, of the bottle form of bichromate; and though it may be useful in exceptional cases for giving large currents, still, as a commercial battery, it is too wasteful to be a success.

A good primary battery should fulfil as many as possible of the following conditions:—

1. Its electromotive force should be high and constant.
2. Its internal resistance should be low and constant.
3. It should be free from polarisation.
4. There should be no consumption of materials when the cell is not in use.

5. The materials should be inexpensive and durable, and the cell should not require frequent renewals of either the aliment or depolarising agent.

6. It should not emit either noxious or corrosive fumes.

No one battery possesses all these qualifications, though many possess several of them in a very marked degree. For any particular class of work it will always be found that one type of battery is more suitable than any other, which is a necessary consequence of the fact that our ideal perfect battery has not yet been constructed.

FORTIFICATION.—V.

BY AN OFFICER OF THE ROYAL ENGINEERS.

CLOSED WORKS.

The points to be attended to in the design of fortifications have already been alluded to; but, in order to understand the relative merits or defects of the various forms of closed works usually met with, it will be best to consider in detail each of these primary conditions, and to omit from present consideration all permanent forts or fortresses.

These latter are in themselves *closed works*, but are generally on such a large scale that they may with advantage be studied separately, as embodying the most approved theories of defence held by the military engineers of a particular nation or period.

Conditions to be fulfilled by Closed Field-works.—In arranging the design of a closed work it will be necessary to determine—

1. The size necessary for the accommodation of any given force.

2. The shape that will be best adapted to the peculiarities of the ground, and to the special defensive objects in view.

3. The modifications of the trace that will be required to ensure a reciprocal defence between the various parts of the work.

Size.—The size of a work depends not merely on the number of men and guns actually required for its defence at any particular moment, but also on whether the defence is intended to last for any length of time, and whether the garrison are to be entirely restricted to the possession of their works.

In the latter case, provision must be made for the fighting space necessary for the men, guns, and the magazines, etc., belonging to them; and there must also be sufficient room in the interior of the work either for an encampment, or for the construction of buildings to serve as barracks.

It rarely happens that field-works are so completely isolated as to require accommodation of this kind for more than a small portion of their garrison, and the length of the sides or faces of a work is, therefore, usually calculated on the space required for the defence itself.

For this purpose it is usual to allow 1 yard lineal of parapet per man, if it is to be defended by single rank, or per file (two men) if double rank are to be employed. A field-gun firing at right angles to a face requires a space of 5 yards lineal to work in; and when a gun is placed at an angle, provided the angle is not very acute, 5 yards on either side of it must be allowed.

Under most circumstances, when the works are of moderately regular shape, the above rule will give ample interior space; but should the shape of the ground necessitate the interior space being much cramped, it must be remembered that, exclusive of the space occupied by traverses, slopes, etc., a minimum of 15 superficial feet per man and 600 superficial feet per field-gun is requisite.

The dimensions of the traverses must vary with the circumstances of each case. On faces liable to enfilade or reverse fire they must be of considerable thickness, to intercept the enemy's projectiles; whereas when they are only intended to protect from the splinters of shells bursting in the work, they need not exceed 6 or 8 feet in thickness.

In addition to the number of troops required for the primary defence of the parapet, a reserve should invariably be allowed for, who should be kept under cover close at hand, to replace casualties, and repel any temporary success that may be gained by the assaulting columns of the enemy.

It may often be necessary to determine the requisite garrison for a work already existing; in which case, deduct from the total length of crest-line the space occupied by the guns and each face, and estimate for the remaining parapet as if to be defended by double rank. The number so obtained will be the total infantry garrison, to which the requisite number of gunners for the service of the artillery must be added.

Occasionally it may be necessary to construct closed field-works near the coast, containing batteries, where the heaviest artillery are to be employed; under these circumstances the dimensions already given must be largely exceeded. As much as 20 feet lineal of parapet is required for working a heavy gun with a lateral range of 60°.

These guns must be placed at intervals of 46 or 50 feet, and a traverse provided for every pair of guns; in addition to which an ample allowance must be made for the space occupied by the magazines, shell-filling rooms, and other adjuncts necessary for the service of modern heavy ordnance.

Closed field-works have, on different occasions, been constructed of very varied sizes, as will be seen from the following extract from a memorandum of Sir J. Jones on the celebrated lines of detached works thrown up at Torres Vedras, by order of the Duke of Wellington:—"The redoubts were made of every capacity, from that which—limited by want of space—was occupied by 50 men and 2 pieces of artillery, to another which was occupied by 500 men and 6 guns."

It may, however, be safely affirmed that all small closed works are bad, and are incapable of maintaining a prolonged resistance to the powerful shell-fire of rifled artillery, unless a greater amount of protection is provided than is usually possible to obtain in the field.

Not only does the fire directed against one side of the work necessarily take in reverse the opposite faces, and thus necessitate such a number of traverses as to seriously cramp the interior space, but the garrison, being crowded into a small area, must suffer fearfully from the effects of shells bursting among them.

The small redoubts which defended the Danish position of Düppel, in 1864 (Fig. 35), are examples of this, for it appears (*vide* "Austrian Military Journal," 1864) that on that occasion the fire of the Prussian artillery rendered the interior of the works so untenable that, at length, in order to obtain more cover, the troops were, to a great extent, temporarily withdrawn from them to a more secure position a short distance in rear, and that one redoubt (No. 5) was stormed by the Prussian troops before the Danes could re-enter their own work.

Shape to suit the ground.—The object of a work may be either that of occupying a particular site, so as to thoroughly defend the approaches to it; or else—although capable of resisting attack on any side—it may be specially designed to bring a heavy fire to bear in certain directions only, its own front being protected by the fire of some collateral works. In the former case the outline or trace must adapt itself closely to the contour of the ground, while in the latter the longest lines of parapet must be those firing in the required direction, irrespective of whether the best possible close defence is thereby attained.

Care must be taken in all cases that the main lines are, if possible, so traced as to be secure from enfilade.

The combination of these principles is by no means easy when the ground to be occupied is irregular, and when there are commanding points within range which may be seized by the enemy; the result being usually a compromise between what is theoretically perfect and what is defective but practicable.

As soon as a general idea of the outline of a work has been decided on so as to carry out the required objects, it then becomes necessary to fit the plan to the ground, so that all the approaches may be thoroughly defended by the fire from the work. In doing this it will often be necessary to modify both the plan and profile previously determined on.

There are certain limits, depending on the slope of the ground, within which the crest-line may be advanced or retired from the top or crest contour of a hill without sacrificing the power of efficiently defending the slopes. As will be seen from Fig. 36, the greatest distance to which it can be retired from the crest will be that which causes the line of fire to graze the slope of the hill, while the minimum distance will be that which allows of the fire passing at such a height above it (3 feet) as shall render it impossible for a body of men to advance unseen. In

this sketch it is, of course, assumed that the parapets are of the same height.

Any further deviation from the crest-line of the hill will involve an alteration of height for the profile, unless it happens that the ground is so steep that, with a small amount of labour, it can be scarped or rendered inaccessible, in which case defence by direct fire is not wanted, and the distant flank fire of another work will suffice.

Flanking Defence.—The provision of a really formidable flanking defence in field-works is always a problem difficult to solve satisfactorily. Their ditches are usually so narrow, and the time necessary for crossing them so short, that it is very desirable the flanking fire on the attacking troops should cover the ground in advance of the counterscarps as well as the ditch itself. To do this, the fire must proceed from the parapet, and an arrangement of trace becomes necessary that has many serious defects. The necessarily increased length of parapet involves more labour, and some of the faces become unavoidably liable to enfilade.

Works in which the fire from the parapets of the flanks defends the ditch are called *forts;* and those in which there is no flank defence, or where the ditches are flanked by buildings in them, are termed *redoubts.*

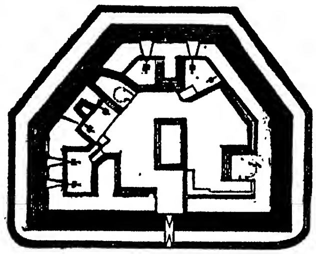


Fig. 35.—REDOUBT AT DÜPPEL.

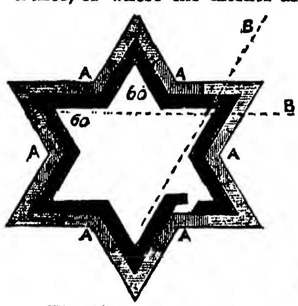


Fig. 37.—STAR FORT.
A, A, A, Undefended Ground in the Ditches.

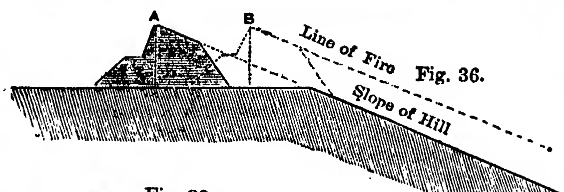


Fig. 36.

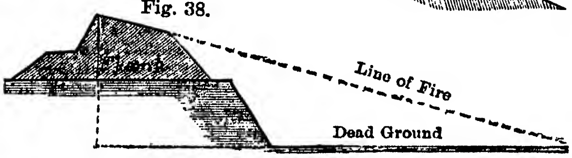


Fig. 38.

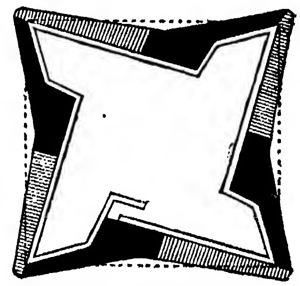


Fig. 40.—DEMI-BASTIONED FORT.
A, A, A, Dead Ground in Ditches.

Forts are not so generally applicable to irregular sites as *redoubts*, and require more time for their construction. There are two types of fort of regular form, viz., the *star fort* and the *bastioned fort,* although a modification of the latter is sometimes employed, called the demi-bastioned trace. This only partially attains the advantages of the bastioned system, as regards flank defence (Fig. 40). In order to obtain flank defence, the parapets of a star fort are traced so as to form a number of salient and re-entering angles, thus giving a star-shaped outline (Fig. 37).

Star forts have many defects, of which the following are the chief. The length of parapet is excessive, in proportion to the area they enclose. All the faces are liable to enfilade and reverse fire, and a portion of each ditch near the re-entering angle is necessarily unseen, and therefore undefended by the fire from the parapets (Fig. 38). The amount of this undefended space in the ditch, or *dead ground*, as it is called, is estimated by multiplying the relief of the flank by the inclination of the line of fire, and is measured on plan from the crest-line, in the direction of the ditch.

A bastion is a lunette connected with other works by lines of parapet called *curtains.* The combination of any two bastions and a curtain is termed a *bastioned front;* and when a bastioned front is traced on each side of the polygon or imaginary figure containing the work, it is called a *bastioned fort.* In a properly-constructed bastion fort, when there has been sufficient time to complete the necessarily wide ditches, the reciprocal defence of the various parts of the work is good; but, on the other hand, the bastions are liable to enfilade and reverse fire, and the length of parapet to be constructed and manned is so very considerable that the interior space would be too much cramped to render this trace advisable for any but large and important positions. To ensure efficient flank defence, without risk of the fire from the flanks striking the defenders of the opposite bastions, care must be taken that the angles of defence are never less than 90°.

It has been found advisable to fix on certain proportions between the various lines of construction, in order to get the best defence possible; and as these proportions are dependent on the size of the polygon on which the fronts are designed, it may be well to state in order the operations necessary to enable a student to draw the trace of a bastioned front (Fig. 39).

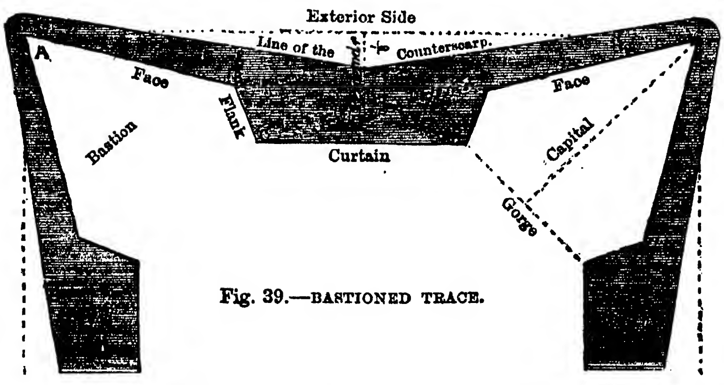


Fig. 39.—BASTIONED TRACE.

1. Bisect the exterior side by a perpendicular line drawn inwards; and make this line 1/8, 1/7, or 1/6 of the exterior, if the polygon of construction is a square, pentagon, or any larger figure.

2. Join the end (E) of the perpendicular with the angles of the polygon, and produce these lines inwards. These are called the *lines of defence.*

3. Set off on each line of defence a distance equal to 2/7 of the exterior side, measured from the angle of the polygon. This will give the *faces of the bastions* (A B).

4. From the ends of the bastion faces draw the *flanks*, making angles of 95° with the opposite lines of defence (B C).

5. From the points at which the flanks cut the lines of defence, draw a straight line connecting the inner extremities of the flanks. This will be the curtain (C D).

In order that the whole fire from one flank may defend those parts of the ditch unseen by the other, it is necessary that the lines of fire should cross at the centre of the curtain, and that the line of the counterscarp should not be traced parallel to the escarp, but be directed on to the shoulder angles of the bastions. As will be seen in the sketch (Fig. 40), this latter arrangement increases the width of the ditch considerably, and consequently involves much time and labour to execute.

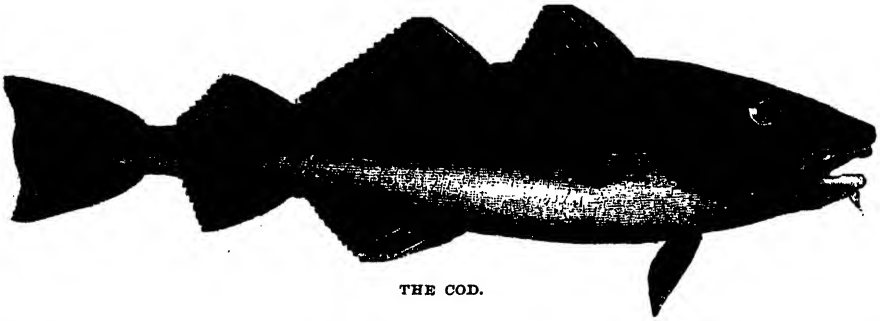
ANIMAL COMMERCIAL PRODUCTS.—XII.

PRODUCTS OF THE CLASS PISCES (*continued*).

THE COD (*continued*).

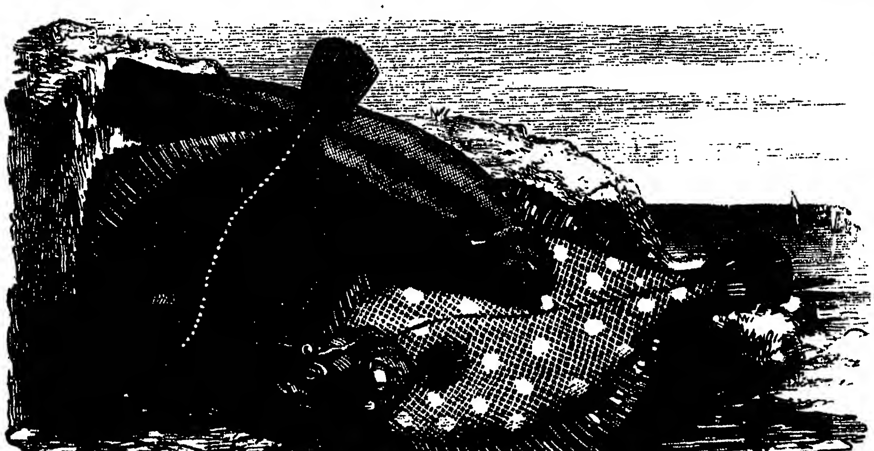
It is the great quantity of cod and its allied kinds, haddock (*Morrhua æglefinus*), tusk (*Brosmus vulgaris*), and ling (*Lotus mola*), which gives to these fish their chief mercantile importance. In 1854, 3,523,269 individual fish of the cod and ling kind were caught, of which 1,385,699 were from the Orkney and Shetland Islands, and the remainder from the other fish-

The total amount of cod, ling, and haddock taken by the fishermen of the United Kingdom every year varies, but is always enormous. Vast quantities of the fishes are dried and cured, and command a steady sale.



THE COD.

The greatest cod fishery* in the world is on the banks of Newfoundland. These banks are based on a large rocky shoal about 600 miles in length and 200 in breadth, being, in fact, the top of a vast submarine plateau, over which the ocean rolls. This place is a great rendezvous for cod, which resort there to feed on the worms, which are plentiful in these sandy bottoms, and on account of its vicinity to the polar seas, whither they return to spawn. The cod are found here in such numbers that although maritime nations have for centuries worked indefatigably at these fisheries, not the slightest perceptible diminution of their abundance has ever been noticed. As long ago as 1676 a cod merchant organised a fleet, and setting out to Newfoundland captured cod to the value of £386,400. The Americans fit out their vessels chiefly at Boston, and thus from their vicinity to these fishing-grounds possess a great advantage over the English. Immense quantities of cod are sent by England, France, and Holland, partly salted and dried, to Southern Europe, chiefly for consumption during Lent and other fasts of the Roman Catholic Church.



THE FLOUNDER, SOLE, AND PLAICE.

Turbot (*Rhombus maximus*).—Taken on all our coasts. The English markets, however, are supplied chiefly with Dutch turbot, which is preferred; these are caught on the sand-banks lying between Holland and the eastern coast of England. The Dutch receive £80,000 per annum for supplying the London markets with turbot; and the Norwegians £15,000 for about 1,000,000 Norwegian lobsters, used partly as sauce for turbot.

Sole (*Solea vulgaris*).—The sole is common on the British coasts, and in season from May to November. The principal fishing stations are on the south coast, from Sussex to Devonshire, especially at Brixham and Torbay. *Plaice*, *flounders*, *dabs*, *halibuts*, etc., are all in great request, but need only be mentioned here.

Lamprey (*Petromyzon marinus*).—An eel-like cartilaginous fish, having a funnel-shaped mouth, surrounded by a circular suctorial lip, by means of which it adheres to stones (Greek, *petron*, a rock; and *muzo*, I suck) and to the bodies of those fish on which it feeds. Formerly the lamprey was considered a and one of our kings (Henry I.) is said to have died in consequence of eating too freely of it. Although not so much in demand now, great numbers are still furnished from the North Sea, the Baltic, and the German rivers, where they abound. Lampreys reach this country packed in jars with vinegar, spices, and bay leaves.

Common Sturgeon (*Acipenser sturio*) belongs to the group of cartilaginous fishes. The body is elongated, spindle-form, and usually from five to six feet in length; the head, which is depressed and produced into a triangular snout, is covered with rows of large tubercular bony plates. The sturgeon is abundant in the seas of Northern Europe, also in the Caspian, the Black Sea, and the Mediterranean, ascending the rivers in great numbers to spawn.

Caviare, which forms an important article of commerce, consists of the roe of different species of this fish, cleaned, washed with vinegar, salted, dried, and then compressed into small cakes, or packed in kegs. Russian caviare—brought from the Caspian and Black Seas—is usually considered the best. Much caviare is also prepared on the shores of the Lower Danube. That furnished by the sterlet (*Acipenser ruthenus*) is so superior that, according to Cuvier, it is reserved for the imperial court of Russia.

Isinglass, another product from these fish, is prepared from their air-bladders. This substance owes its commercial value to its extremely delicate fibres, which operate mechanically in the clarification of white wines and malt liquors. It is also much employed in cookery. Russian isinglass is preferred to that from Hungary and Germany.

PRODUCTS OF THE SUB-KINGDOM MOLLUSCA.

Mollusca (Latin, *mollis*, soft).—Soft-bodied, invertebrated animals, devoid of an internal bony skeleton, having a gangliated nervous system, the ganglia, or knots of nervous matter, being irregularly dispersed in different parts of the body. They

* For a full account of the Fishing Industries of this and other countries, the reader is referred to "The Fisheries of the World," by F. Whymper (Cassell & Co., Limited).

have a distinct pulmonary or branchial circulation, white or bluish blood, and in most cases a shell covering, in which the animal resides. This is secreted by the margin of a peculiar organ termed the mantle, or an external fold of the skin reflected over the body. Many of the lowest and some of the highest of the Mollusca are naked, or a horny and testaceous rudiment of a shell is developed, but remains concealed beneath the substance of the mantle. When, however, the shell is so much enlarged that the contracted animal finds shelter within or beneath it, then the mollusk is termed testaceous (Latin, *testa*, a shell). We shall confine our notes to the testaceous Mollusca, as commercially they are the most valuable. The following are the chief classes of the Mollusca :—

1. *Cephalopoda*, or *head-footed* (Greek, *kephale*, head, and *pous*, a foot), having the head well developed, protruding from the mantle, and furnished with tentacula, serving for the seizure of food and for crawling. Examples: nautilus and cuttle-fish.

2. *Gasteropoda*, or *belly-footed* (Greek, *gaster*, the belly, etc.), crawling by means of a broad muscular disc on the lower surface of the body, which serves as a substitute for legs. Examples: *Helix hortensis*, the garden snail; *Limnæa stagnalis*, the pond snail; and *Limax agrestis*, the field slug.

3. *Pteropoda*, or *wing-footed* (Greek, *pteron*, a wing, etc.), comprehending a few mollusks which have a natatory wing-like expansion on each side of the head. They are naked, or provided with a delicate univalved shell. Example: *Clio borealis*. Most of the species of the class *Pteropoda* are fossil, but a great many are still found in existing seas, living near the surface.

The *Clio borealis* forms the food of the whalebone whale. It is an inch long, uses its light shell as a boat, its wing-like fins as oars, and so navigates, in countless numbers, the tranquil surface of the Arctic seas.

4. *Conchifera*, or *shell-carriers* (Latin, *concha*, a shell, and *fero*, I carry), including all the bivalved mollusks not *Brachiopods*. Examples: oyster, mussel, and pearl oyster.

5. *Brachiopoda*, or *arm-footed* (Greek, *brachion*, an arm, etc.). —Bivalves devoid of locomotive power, and attaching themselves to foreign bodies: they are furnished with two long ciliated arms developed from the sides of the mouth, which, by producing currents, bring food to the animal. Examples: *Terebratula* and *Lingula*.

APPLIED MECHANICS.—VII.

BY SIR ROBERT STAWELL BALL, M.A., LL.D.,

Astronomer-Royal for Ireland.

MACHINERY USED IN AGRICULTURE.

MECHANICAL APPLIANCES USED IN PREPARING THE SOIL —MACHINES USED FOR SOWING—MACHINES USED IN REAPING.

THE application of machinery to the different branches of agriculture is of considerable antiquity. Not to mention the simple implements such as spades, rakes, etc., more complicated machines have been in use since the earliest times. A form of plough which was used by the ancient Romans is still employed in parts of France and Italy. The ploughs with which we are familiar are, in fact, to a certain extent on the type of the ancient instrument, but have received from time to time improvements which the experience of successive generations of cultivators of the soil has suggested. The Romans were also accustomed to irrigate their land by artificial means when circumstances were suitable, and this process is still recognised as one of the most scientific applications of capital to agriculture. In this lesson, however, we propose rather to sketch the present condition of agricultural machinery than to trace its history in successive ages. There are other applications of science to agriculture besides those which relate to the employment of machinery; notably among these is the service rendered by chemistry in the analysis of soils and manures: with such matters we have nothing to do. This lesson is intended to describe the mechanical appliances employed, first, in the preparation of the soil; secondly, in the putting in of the crop; and, thirdly, in the gathering of the crop. Those who wish to pursue the subject further will find a considerable amount of information in Donaldson's "British Agriculture," a work to which I must acknowledge my obligations in the preparation of the present lesson.

MECHANICAL APPLIANCES USED IN PREPARING THE SOIL.

Land may suffer on the one hand from an excess of water, on the other hand from a deficiency in that fertilising liquid; in either case mechanical appliances must be resorted to as a remedy. In the one case we must by drainage endeavour to remove the superfluity, in the other case by irrigation we can supply the water which is necessary. There is no occasion, however, to do more than mention these important operations here, as the various methods employed for carrying off surplus water from the soil by artificial means, and distributing fertilising currents over parched grass-lands, are fully described in the lessons in "Agricultural Drainage and Irrigation" given in this work.

Drainage and irrigation are most necessary mechanical operations in the treatment of the soil prior to its being actually broken up for the purposes of tillage. To this important subject we now proceed. The earth is a very weighty material, and the labour that is expended upon breaking it up consists in great part of the actual exertion of raising its weight through a small height and replacing it again. Thus the soil that covers an acre to the depth of four inches weighs from 600 to 700 tons, and if in the process of breaking up this mass has to be raised even to the height of a few inches and replaced again, the consumption of work is very considerable. But in addition to the mere weight of the soil, there is its tenacity also to be overcome. It is probable that in many soils, if not in most, the force requisite to overcome this exceeds that which is due to the weight of the soil alone. Thus in digging a garden with a spade, though the sharp edge of the spade divides the soil, yet the mass that is being removed has to be torn away from the lateral portions, and in tenacious soils, as every one knows, this resistance is very great. A spade is, in fact, a powerful lever of the first order. The power is applied by the hands at one end, the fulcrum is the upper portion of the spade where it is in contact with the surface of the soil, and the load is the mass of earth which is being removed. The leverage in such an implement is at least sevenfold or eightfold, and even with this mechanical advantage the operation of digging is one of great labour.

On the large scale, the use of the spade is, of course, replaced by the plough. We here abandon the principle of the lever as a mechanical power, but we replace it by the wedge which we have already described. In reality the ploughshare is a wedge which inserts itself into the soil, and overcomes both the resistance of the weight of the soil and also that presented by its tenacity.

It will be well to mention the names which are applied technically to the different portions of a plough. We shall then consider the principles on which the action of the plough depends. The bottom of the plough is called the *sole*; to the point of this is fixed the *share*; the beam projects in the front of the plough, and to it the oxen or horses are attached. Attached to the beam in a vertical position is the *coulter*; this cuts a vertical section in the ground; while the point of the share, expanding into a fin, cuts a horizontal slice from the ground under it. The *mould-board* is placed behind the fin, and serves to raise up and remove the slice which has been cut by the coulter and share. These different portions of a plough will be seen from the illustration of a very improved form of plough (Fig. 3).

The action of the plough is therefore threefold. First, the vertical cut by the coulter, then the horizontal cut by the share, and, finally, the turning over of the portion thus cut by the mould-board. Experience has done more in devising the form of the plough than direct application of science. The actual problem of finding the best possible form of plough would be a very difficult one, even if all the conditions of the question were known; but owing to the varying conditions of soil, it is almost impossible to devise any very rigorous statement of the problem which the best construction of a plough would involve. We shall, however, give a short account of what is known as to the principles on which the plough acts. The accompanying figure (Fig. 1) is taken from the "English Cyclopædia," in which an excellent account of the theory of the plough will be found. Let A B D C represent the slice of ground which is being re-

moved by the plough; A C is the vertical cut which is made by the coulter; C D the horizontal cut which is made by the share. The object of ploughing is to turn this sod up to the vertical position, D c a b, and then to tilt it over to the inclined position, d′ b′ a′ c′, so that the original surface, A B, is changed into the under surface, a′ b′; the object of this is to kill the weeds or grass that may be on the surface by burying them, and at the same time to expose as much of the soil as possible to the action of the atmosphere. The problem, then, which the mould-board has to solve, is to effect this operation as uniformly and with as little waste of power as possible. This condition points out that the surface of the mould-board must be that of a screw, which might be produced by a line nine or ten inches long, which revolved uniformly about an axis through an angle of 135°, while at the same time it travelled along the axis through a space of three or four feet.

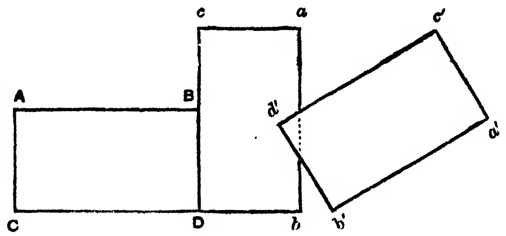


Fig. 1.

The portions of a plough are now generally made of cast-iron, and a very beautiful property of cast-iron is made use of in the point of the share. It is well known that cast-iron when poured into an iron mould becomes intensely hard. It is called chilled iron, and is used where ordinary cast-iron would be too soft. In casting the share, the lower surface of its point is in contact with iron; the consequence is that the under surface of the share is of chilled iron, while the upper surface is of ordinary cast-iron. The effect is that the upper part of the point is worn away more rapidly than the under surface, and consequently the share always presents a sharp edge. The actual draught required in drawing a plough is very variable; but it may, on the average, be taken at about three hundred-weight. This point is carefully attended to in comparative estimates of the merits of different forms of plough. It is ascertained by attaching a dynamometer to the plough, and applying the power of the horses to the dynamometer.

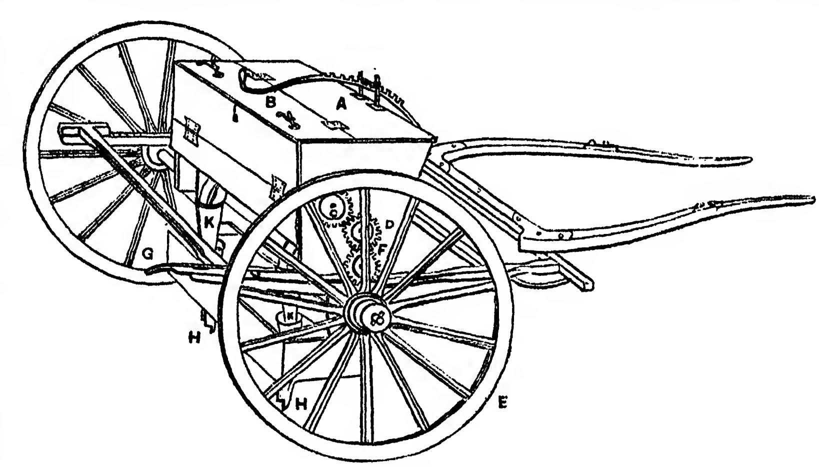


Fig. 2.

It is usual now to employ, when the circumstances will admit of it, steam power for drawing ploughs, in place of the muscular power of animals. To render this plan capable of economical adoption, a large area must require to be ploughed, and the land should be tolerably level. The steam-engine which gives motion to the ploughs is in one corner of the field, and its power is communicated by means of wire ropes, which passing over pulleys properly attached at the margin of the field, are fastened to the ploughs. One engine is thus enabled to work several ploughs simultaneously.

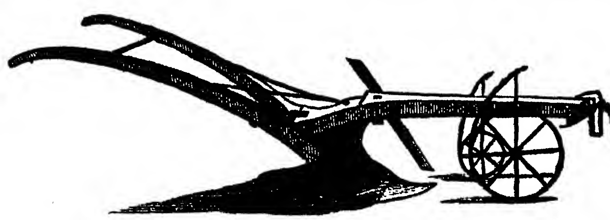


Fig. 3.

The next operation to which the land is subjected is that of harrowing. This is of a very simple character; it consists merely in drawing a frame covered with spikes over the newly-ploughed fields, for the purpose of breaking up the clods which the plough has turned up. Nothing further need be said of this process.

MACHINES USED FOR SOWING.

In sowing, it is desirable that the seed be distributed with regularity over the surface, and in the quantity which experience has found most desirable for each kind of seed. It is also necessary that the seed be deposited at precisely that depth in the soil at which it will be most favourably circumstanced for germination. Now machinery, by the regularity and certainty of its action, is eminently adapted for the purpose of placing seed at the right depth and in proper quantity. It is not, therefore, merely as a labour-saving agent that sowing machines are useful; they accomplish the work with a perfection that it is not possible for labour unassisted by their means to attain. It is found that seeds sown in drills yield a crop more economically than when the seeds are sown broadcast. The machines which are employed in sowing are therefore adapted for depositing the seed in drills. These machines are themselves technically called *drills*, in consequence of the object for which they are employed. In Fig. 2 is shown what is called the Northumberland turnip drill, used, as its name expresses, for sowing turnip seed. It is a very perfect instrument of its kind, and a description of it will embrace the principal features of all the better machines of this class. We have borrowed this figure, and the accompanying description of it, from the "English Cyclopædia." This machine adapted to introduce ground bones, or other manure of the same class, into the ground simultaneously with the seed. "The body of the drill consists of two boxes, A and B, divided by a partition between them, and each again divided into two by another partition at right angles to the first. Into the box A is put the manure, into B the seed. Iron slides are fixed on each compartment to regulate the supply of seed or manure. In the lower part of the box, and just before the opening, which is regulated by the slides, are two cylinders, one for the box A, and the other for B. On the cylinder in A are fixed shallow cups with short stems which dip in the boxes, and carry a certain quantity over the cylinder as it turns, which falling in the funnels, K, K, is deposited in the furrows made by the coulters, H, H. The cylinder in the box B has projecting pieces of iron with a small cavity in each near the end, which takes up a very small quantity of seed, and discharges it in the same manner into the two funnels, K, K. On the axis of the wheel E is a toothed wheel, which turns a small wheel, D, on the axis of the cylinder in A, and thus turns

another wheel, C, on the axis of the cylinder in B. As these two wheels move towards each other, the two cylinders turn in contrary directions, which is a convenience in turning the seed and the manure into the funnels at the same time. The wheel F may be lifted up by means of a lever G, and then the cylinders do not revolve. There are various other contrivances which cannot easily be explained without a more detailed figure of the different parts." It is always difficult to convey an adequate idea of complicated machines by description: an examination of the machine itself, which is to be met with in any agricultural museum or show, will explain its action better than any description, however lengthy.

MACHINES USED IN REAPING.

We have seen how machinery aids in preparing the soil and sowing the seed: we have now to examine its utility in enabling the farmer to realise the fruits of his labour. Reaping-machines are of very modern construction; they are eminently useful as labour-savers, and simultaneously with the rise in wages of agricultural labourers have reaping-machines come more and more into use. They vary very much in external appearance, but certain principles appear to be common to all the different forms. The blade of the reaping-machine consists of a series of notches, as shown in Fig. 4. These notches are sharpened

Fig. 4.

on their edges by grinding-stones of peculiar construction. If we conceive two blades of this shape, one immediately overlying the other, and if the one be held fast and the other be made to oscillate backwards and forwards rapidly, we have the essential principle of a reaping-machine. These blades are carried a few inches above the surface of the ground, and one of them is made to oscillate by means of a mechanical connection with the wheels of the machine; a series of arms force the straw into the notches, and it is immediately cut across by the moving edges, and the machine neatly deposits the corn which has been cut.

We have in this lesson been able to give only the merest outline of the debt which modern agriculture owes to machinery. There are innumerable appliances into which we cannot enter. Thrashing and winnowing machines would form a suitable sequel to reaping-machines. We might also speak of machines for cutting down trees, for removing stumps of old trees from the ground, and machines for excavating earth. There are numerous machines in constant use in America with which we are not familiar here. There the high price of labour has rendered all labour-saving appliances of far greater economic importance than in older countries where the population bears a higher proportion to the capabilities of the soil for production.

PRACTICAL PERSPECTIVE.—I.

INTRODUCTION.

The intimation that "these lessons are written to supply a want" has become so hackneyed, that it is only repeated here because no other sentence would so well express their real purpose; and it is hoped that by their publication a series of really elementary lessons will be given which will be useful not only to artisans and teachers, but to the public generally.

The words used in the introduction to the lessons in "Practical Geometry applied to Linear Drawing" refer equally to these lessons:—"The subject is not treated as a mathematical, but as a thoroughly practical one, and therefore no absolute system of reasoning is attempted; still, it has been thought right to give some simple and familiar explanations of the properties of the various figures, and the principles upon which their constructions are based, as it must be obvious that the more the mind comprehends of the relation of one line and form to another, the more will the eye appreciate beauty and refinement, and the more intelligently will the hand execute."

In pursuance of this plan, only just as much of the theory of Perspective is given as will enable the student to comprehend the subject; and an endeavour is made, as the lessons advance, to show the application of the principles, and of the few rules laid down.

The studies are very carefully graduated, commencing with the perspective projection of single points, and proceeding in succession to the consideration of lines, planes, and rectangular solids, in the foreground and in the distance, when parallel or at an angle to the picture.

The course next takes up the delineation of polygons, prisms and pyramids, circles, cylinders, and arches.

The examples are all clearly drawn, the working lines being shown; the lettering is plain; and the instructions as simple and brief as is consistent with the proper explanation of the subject.

Exercises are added in order that the student may test whether he has fully comprehended what he has been taught, and whether he can vary the circumstances whilst applying the principles. This will counteract the tendency to *copy* the *diagrams* so often met with.

These exercises will also be found most valuable to teachers, who are advised to write them on the black-board, causing each student in the class to take a different centre, points of distance, scale, etc., whilst still working out the subject according to the other data given.

The student is urged to work the figures contained in lessons in "Practical Geometry applied to Linear Drawing" either before, or concurrently with Perspective, as he will otherwise find himself constantly in the awkward position of being unable to construct the geometrical form which he is endeavouring to put into perspective. It will also be of advantage to him to study "Projection" either previously to, or at the same time with, these lessons, as he will then be able to observe the changes of form caused by the parallel lines of the one system and the convergent lines of the other, whilst the knowledge of developments will enable him to understand the true forms of the surfaces which become so much altered by Perspective.

All the studies are based upon the actual experience gained during nearly twenty years' teaching, in which the inquiries of students, their difficulties, and the errors into which they are most liable to fall, have been most carefully noted; and it is therefore hoped that these lessons may do the work at which they aim efficiently, so that the term "Perspective," instead of being uttered with dread, as a mysterious art known only to a few, may become as familiar as a household word to the many, and thus, by a knowledge of its principles, our students may be enabled, not simply to work out the lessons with their instruments, but to sketch with rapidity and correctness, whether from the object or from memory. *When Perspective is thus understood, it becomes indeed the grammar of a universal language.*

PRACTICAL PERSPECTIVE.

Perspective is that branch of "Projection" which teaches the mode of drawing objects, etc., as they *appear* to the eye of the spectator in whatever position he may be placed.

This appearance will, of course, be altered by (1) the distance of the object from the spectator, and (2) its position.

The moment we open our eyes a flood of light enters, and the rays which pass from the surfaces of every object are thus conveyed by the eye to the brain.

As these rays pass from the entire surrounding space through the small opening called the pupil of the eye, they are said to "converge,"* and thus form what is called the "visual angle."

Of course, the angle at which the outer rays meet depends on the size of the aperture in the eye of different persons. For perspective purposes, however, an average angle has been generally adopted—namely, that of 60°; for experience has shown that the majority of persons can see, let us say, a line, A B (Fig. 1), when the distances from A to C (the station of the spectator) and from B to C are equal to the length of the line; and it will be seen that an equilateral triangle is thus formed, the angles of which, as has already been shown in "Practical Geometry applied to Linear Drawing," are all 60°.

But the rays do not proceed from a single line, thus forming a *plane* triangle, but from the entire surrounding space. The

* *Converge.*—To incline together, so as ultimately to meet in a point.

triangle A B C is thus, as it were, rotated on the central line C D, and a cone (that is, a *solid* triangular body having a circle for its base) is formed. The line C D, or axis on which the triangle has been rotated, is called the central or principal visual ray.

It will be clear, then, that since the base of this cone (Fig. 2) comprehends all that can be seen when looking straight forward, our entire picture must be contained within it.

The apex, C, of the cone is called the *station-point*, as being the other. Now let threads attached to the angles of the cube pass through small holes in the plane in straight lines to the eye. Then if these holes are joined by lines, the exact perspective appearance will be obtained.

Now it is easily understood that this centre of vision will be moved as we turn round, and hence some objects will gradually be removed from our view, whilst others become visible; but so long as we do not stand on higher or lower ground, the *height* of our eye will remain the same.

Fig. 1.

Fig. 2.

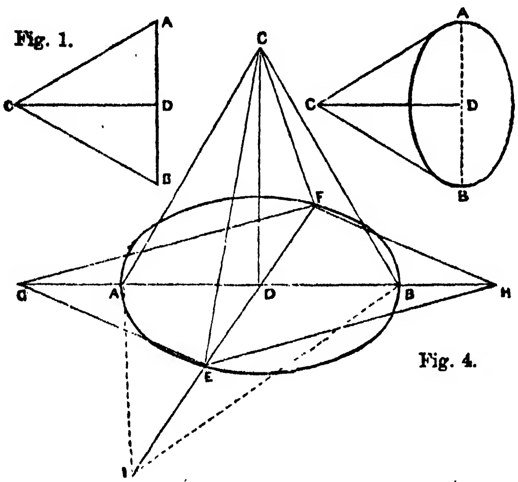


Fig. 4.

Fig. 5.

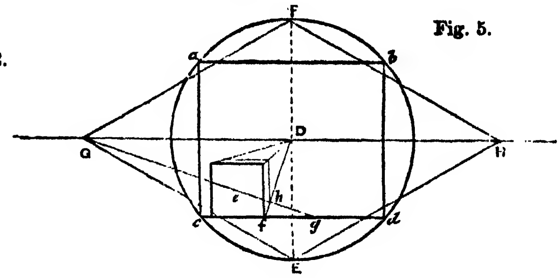


Fig. 6.

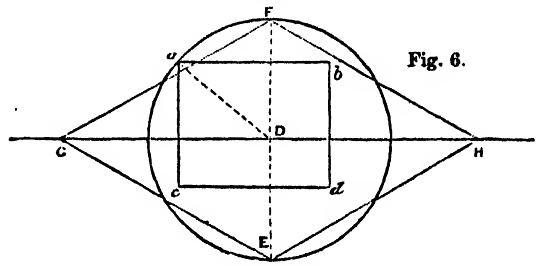
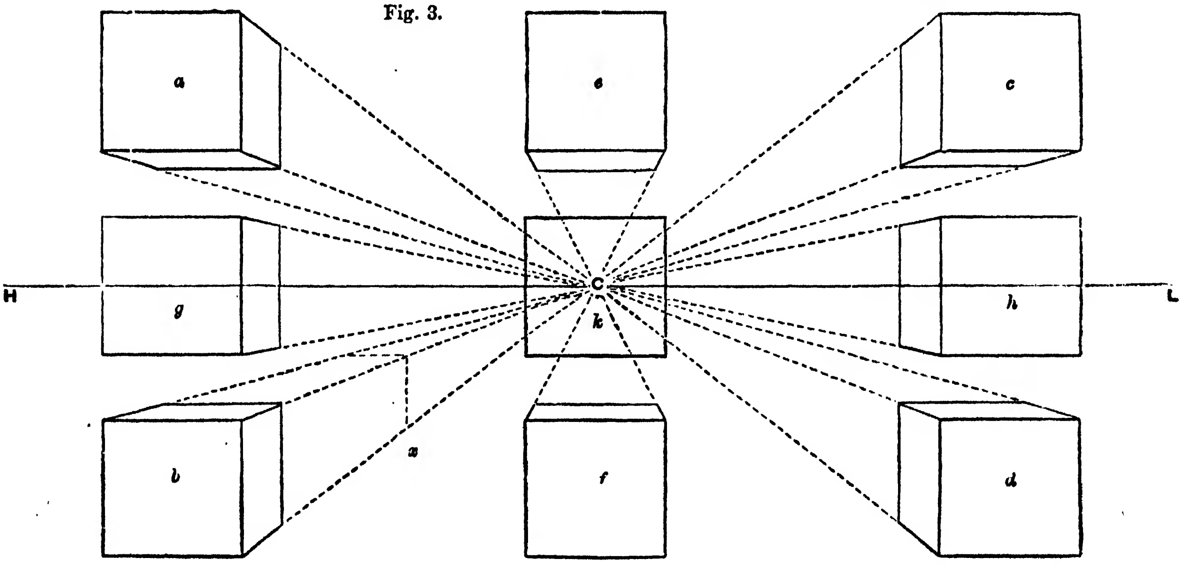


Fig. 3.



the station of the spectator, or the *point of sight*, since it is the point from whence the sight is obtained.

The opposite end of the central ray is the centre of the base of the cone of rays, and is therefore called the *centre of vision*.*

The surface on which we draw is called the *picture-plane*. It is supposed to be transparent, and (as a rule) to be placed vertically between the spectator and the object; the rays passing from the object through this plane give the apparent form. Thus, let a plane stand on its edge on a table, and let a cube be placed on one side of it, the eye of the spectator being on

* As, however, in looking forward from the point of station, the point C (the one end of the central ray) is immediately in front of the centre of the circle, the point has generally been termed the "point of sight."

The *horizontal line* is a line drawn through the centre of vision in a horizontal position, as its name implies. It shows the height of the eye of the spectator in relation to the objects drawn. This is shown in Fig. 3.

Here C is the centre of vision, and H L the horizontal line. The cube lettered *a* is above the level of the eye of the spectator, and *b* is below. Thus the under surface of *a* and the upper surface of *b* are seen. Both are on the left of the spectator, and thus the right side of each is visible.

The cubes *c* and *d* are similarly placed as to the horizontal line, but being on the right of the spectator, their left side is presented to view.

The cube *e* is above and *f* below the horizontal line, and thus the bottom of the one and the top of the other is seen; but as

they are immediately above and below the centre of vision, neither side is visible.

Again, the cube *g* is on the left and *h* is on the right of the spectator, but both are on a level with the centre of vision, and therefore only the side of each is seen, but neither top nor bottom; whilst in *k*, which is immediately opposite to the eye of the spectator, none of the sides, excepting that which forms the front, are visible.

It is necessary, however, to fix in a definite manner the positions of the lines which represent the distant edges of the objects, for it will be evident, on referring to the cube *b*, that if these were placed at *x*, the object would appear a long balk of timber instead of a cube. The correct proportion is, however, obtained by means of points, of which we shall now speak.

The *points of distance* represent the distance of the eye from the picture.

To illustrate this, let us now turn to Fig. 4. Here A B C is the cone of rays standing on its base. Now, as the picture-plane forms a part of that base, it will be clear that the length of the axis, or central ray, C D, represents the distance of the eye (situate at the apex of the cone) from the picture, and it is now required to lay this length down on our paper.

It has been said that the cone adopted for the purposes of perspective has its slanting side equal to the diameter of its base. Therefore any section taken through the axis would be an equilateral triangle, as E C F.

Now, if we imagine this equilateral triangle rotated on the line E F, first on the one side and then on the other, we shall obtain G and H, which will be the points of distance, for D G and D H will be equal to D C, the altitude of the triangle or axis of the cone, which is necessarily the distance of the spectator from the picture.

Fig. 5 is the plan of this cone.

Having drawn the picture-plane, *a b c d*, and the base of the cone surrounding it, draw the perpendicular line E F.

From E and F, with radius E F, describe arcs cutting each other in G and H, which will be the points of distance.

To show at once the use of these points, draw the square *e*, and from its angles draw lines to D (representing rays of light passing to the apex of the cone).

Now from the point *f* of the cube set off what you know to be the *real* width of the distant side (which in this case will be equal to the width of the front, the object being a cube), namely, *f g*.

From *g* draw a line to G, which, cutting *f* D in *h*, will give the point at which the distant edge of the cube is to be drawn. This figure may be slightly in advance of the student's present knowledge, and is merely introduced here so that the purpose of the points of distance may as soon as possible be made evident. The steps leading to this subject will, however, be clearly shown hereafter.

The centre of vision, although the centre of the base of the cone of rays, need not necessarily be the *centre* of the *picture*, for although the picture-plane must be contained within the circle, it need not occupy the whole, but it *must* touch the circumference at *one* point.

To find the points of distance when the picture-plane, *a b c d* (Fig. 6), and the centre of vision, D, are given—

Through D draw the horizontal line.

From D, with radius D *a*—that is, from the centre of vision to the most distant angle of the picture-plane—describe the base of the cone of rays.

Draw E F through D, and with E F as radius, describe arcs cutting each other in G, H, which, as before, will be the points of distance.

The bottom line of the picture, *c d*, is called the *picture-line*.

It is not always necessary to employ the whole of the picture-plane or base of the cone of rays; it is, therefore, generally enough to state the height of the eye of the spectator, and his distance from the picture. This plan will now be adopted, as we shall be thus enabled to employ the whole space at our disposal in delineating the subject of the study. The centre of vision will throughout the lessons be called C, and the points of distance, P D. It may also be as well to remark that wherever it is necessary to speak of the horizontal line and refer to it by letters, the letters H L will always be used to denote it.

TECHNICAL EDUCATION AT HOME AND ABROAD.

VIII.—EVENING SCIENCE INSTRUCTION

BY SIR PHILIP MAGNUS.

spoken of the difficulty of securing a guarantee that the instruction as given in ordinary science classes is satisfactory without the aid of a central authority. If, however, teaching were paid for by the town, it might be tested by inspectors appointed by the municipality, and under these circumstances it might be, in many cases, better adapted than now to the special requirements of those receiving it; but when the instruction is State aided, it must be State controlled, and the centralisation of the superintending authority is not compatible with that freedom and elasticity of teaching which is an element of the highest value in every kind of education.

On the other hand, whilst perfection cannot be expected in any general system such as that carried out under the direction of the Science and Art Department, it may be contended that the assurance that the instruction is good as certified by the results of the examinations, and the influence of such examinations, conducted by men of the highest scientific eminence, upon the methods of instruction, counterbalance some of the disadvantages of the system. Moreover, it cannot be too often repeated that the great value of science teaching does not lie so much in the information imparted as in the power of observation and in the accuracy of thought it gives rise to; and further, that the limitation of instruction in science to those special subjects that may seem to lead up to the requirements of the student is calculated to narrow the student's view, and to give the appearance of completeness to what is really very superficial knowledge. But the great value of science to the artisan is in enabling him to understand the cause of unexpected appearances; and for this purpose he may often require to know facts in science which would seem to be quite remote from those connected with his ordinary work. It is on account of the difficulty of providing for the unseen, and because most natural phenomena are complicated, and require for their explanation the principles of various branches of science and facts widely separated in the text-book arrangement of a subject, that it is thought better by some authorities to give the same systematic teaching to all students, be their occupations or their requirements what they may, than to attempt to adapt the teaching of the elements of science to what may be thought to be, but to what may not prove to be, the student's real wants. On these grounds, the teaching of the elements of chemistry or physics to artisans without any reference to their application is very frequently justified as the most fitting introduction for more advanced scientific instruction, or for the subsequent study of the technology of separate industries. By itself, it is clearly not enough to prove serviceable to artisan students who are already engaged in trade, and who are desirous of seeing the connection between the problems they are daily meeting and the principles of science they learn in the class-room. Supplementary instruction of this kind, connecting the teaching of pure science with workshop practice, artisans in this country have now the opportunity of obtaining in the classes organised by the City and Guilds of London Institute, to which full reference will be made later on. But before passing on to the consideration of this subject, it will be well briefly to summarise the assistance that the State affords to science teaching, seeing that it includes much more than the payment on the results of the examination of students of evening classes.

AID AFFORDED BY THE SCIENCE AND ART DEPARTMENT TO INSTRUCTION IN SCIENCE.

The Department:—

I. *Holds public examinations;* on the results of these examinations are awarded—

a. To teachers:—Payments on results on account of the instruction of the industrial classes, as defined below:—(*a*) Persons in the receipt of weekly wages, and their children if not gaining their own livelihood. (*b*) Teachers and pupil-teachers of elementary schools in connection with the Education Department, Whitehall, or the National Board of Education, Ireland, and their children if not gaining their own liveli-

hood. (*c*) Persons in the receipt of not more than £200 per annum from all sources, and their children if not gaining their own livelihood. (*d*) Scholars in Public Elementary Schools within the meaning of the Elementary Education Act, 1870.

The payments are as follows :—(*a*) In the elementary and the advanced stages of each subject, except Practical Chemistry and Practical Metallurgy, £2 and £1 for a first or second class respectively. (*b*) In honours, £4 and £2 for a first or second class respectively. (*c*) In Practical Inorganic and in Practical Organic Chemistry and in Practical Metallurgy, £2 and £1 for a first or second class respectively in the elementary stage; £3 and £2 for a first or second class respectively in the advanced stage; and £4 and £3 for a first or second class respectively in honours.

β. *To students* :—(*a*) Certificates. (*b*) Prizes in advanced stage only. (*c*) Medals in honours stage. (*d*) Scholarships :—

A. Elementary :—(*a*) In the *Elementary School Scholarship* £5 are granted to the managers of any elementary school for the support of a pupil selected by competition, if they undertake to support him for a year, and subscribe £5 for that purpose. The payment of £5 by the Science and Art Department is conditional on the scholar passing in some branch of science at the next May examination. (*b*) In the *Science and Art Scholarship*, which is of a more advanced character, a similar contribution of £5 is required on the part of the locality, and a grant of £10 is made by the Department towards the maintenance, for one year, of the most successful pupil or pupils in elementary schools who have passed certain examinations in science and in drawing.

B. Advanced :—(*a*) *Local Exhibitions* to enable students to complete their education at some college or school where scientific instruction of an advanced character may be obtained. Grants of £25 per annum, for one, two, or three years, are made for this purpose when the locality raises a like sum by voluntary subscriptions. And if the student attend a State school, such as the Normal School of Science and Royal School of Mines in London, or Royal College of Science in Ireland, the fees are remitted. The exhibition must be awarded in competition. (*b*) *Royal Exhibitions* of the value of £50 per annum, tenable for three years, to the Normal School of Science and Royal School of Mines, London, and the Royal College of Science, Dublin, are given in competition at the May examinations. Seven are awarded each year—four to the Normal School of Science and Royal School of Mines, and three to the Royal College of Science. (*c*) *National Scholarships*, tenable at either the Normal School of Science and Royal School of Mines, London, or at the Royal College of Science, Dublin, at the option of the scholar. These scholarships entitle the holders to free instruction for three years at either one of the two institutions specified, and to a maintenance allowance of 30s. a week during the session of about forty weeks each year. The scholarships are restricted to students of the industrial class. Twelve are awarded each year. (*d*) *Free Studentships*. Eighteen free studentships, six open each year, to the Normal School of Science and Royal School of Mines. (*e*) *Whitworth Scholarships*.

II. *Holds examinations in Training Colleges*.

III. *Encourages organised science instruction* by offering the following special payments :—In day schools, 10s. on account of each pupil who attends the full course of instruction, is present during 250 attendances of the school, and passes in one of the subjects of study laid down for his year. The school year is held to terminate for this purpose on the 1st May. In night schools, 5s. on account of each pupil who attends the full course of instruction, is present during 75 attendances of the school, and passes in one of the subjects of study laid down for his year. The school year is held to terminate for this purpose on the 1st May.

IV. *Makes grants towards buildings* for science instruction. A grant in aid of a new building, or for the adaptation of an existing building for a School of Science, may be made at a rate not exceeding 2s. 6d. per square foot of internal area, up to a maximum of £500 for any one school, provided that certain conditions are complied with and that the school be built under the Public Libraries and Museums Act, or be built in connection with a School of Art, aided by a Department building grant.

V. *Lends collection of apparatus* to schools for short periods. With a view to the more efficient instruction in science schools, suitable collections of apparatus have been formed specially adapted for the illustration of science teaching. Duplicate sets of this apparatus have been formed, and applications can be received from science schools for lending them for a short period. No set of apparatus will be allowed on loan in any science school for a longer period than three weeks. Teachers will be allowed to use the apparatus for the purpose of demonstrating before their classes; but they must not be used by the students, and any damage which the apparatus may sustain whilst in the possession of the class will have to be made good at the expense of the Committee.

VI. *Grants aid toward the purchase of* :—(*a*) Fittings. (*b*) Apparatus. (*c*) Diagrams. (*d*) Books. A grant towards school fittings of special construction for laboratories or lecture rooms, and the purchase of apparatus, diagrams, etc., not exceeding 50 per cent. on the cost of them, may, at the discretion of the Department, be made to science schools, provided they are in connection with public institutions; are taught by duly qualified teachers; are under the supervision of Committees properly constituted, and approved by the Department. Application must be made to the Department and approved before the apparatus or fittings are ordered, or no grants will be allowed. The apparatus must be kept on the school premises.

VII. *Trains teachers* :—*a*. At the Normal School of Science :—(*a*) Ordinary courses. A limited number of teachers are admitted, who receive free instruction and 21s. a week. (*b*) Short summer courses to select teachers, who receive £2 a week and railway fare. β. At provincial colleges, by paying half the fees for two days a week laboratory work.

VIII. *Makes grants in aid of the travelling expenses of teachers* :—A teacher giving instruction in science in several villages or small towns may receive several special grants in aid of his travelling expenses. These special grants are only to be made provided that there is a local organisation for a general system of science instruction, that the teacher is highly qualified, and that local teachers are not available.

IX. *Holds special examinations for seafaring men* :—In addition to the ordinary science examinations in May, class examinations may be held in mathematics, navigation, nautical astronomy, and steam, for the benefit of seafaring men—and for them only—three times a year in all seaports where Local Committees are formed and are willing to undertake them. These examinations take place in the beginning of March, September, and December.

X. *Provides short courses of lectures to working men at* :—(*a*) Museum of Practical Geology, Jermyn Street. (*b*) Normal School of Science. (*c*) Royal College of Science, Dublin.

ART CLASSES.

Of no less and possibly of more importance as a part of technical education than science teaching is instruction in art. Every town in Great Britain of any pretensions has now its art school, which is frequented in the daytime chiefly by amateurs, and in the evening by persons engaged in productive industry, who have found out for themselves the value of drawing in all its stages in advancing the work in which they are engaged. The organisation of art schools in this country dates back from 1836, when they were established as "Schools of Design." In 1852, these schools were re-organised as the Department of Practical Art, the object of the Department being :—(*a*) The promotion of elementary instruction in drawing and modelling; (*b*) Special instruction in the knowledge and practice of ornamental art; (*c*) The practical application of such knowledge to the improvement of manufactures.

Nothing could be more practical or better calculated to provide technical instruction than an organisation such as this.

BUILDING CONSTRUCTION.—X.

ARCHES (*continued*).

BEFORE, however, entering into the brick construction of the arch shown in Fig. 68, which was given in our last lesson on this subject in page 265, it is necessary to speak of the wooden supports temporarily employed in the construction of arches. These will be fully described in other lessons; still it is neces-

*

sary incidentally to mention them; for although they are really branches coming under the head of constructive carpentry, yet it is important that their general purpose, principles, and application should be thoroughly understood by the bricklayer and mason. The temporary wooden constructions referred to are called "centerings," and consist of an assemblage of timber beams so disposed as to form a strong frame; the convex or outer frame being of the exact form of the intrados of the arch which is about to be erected.

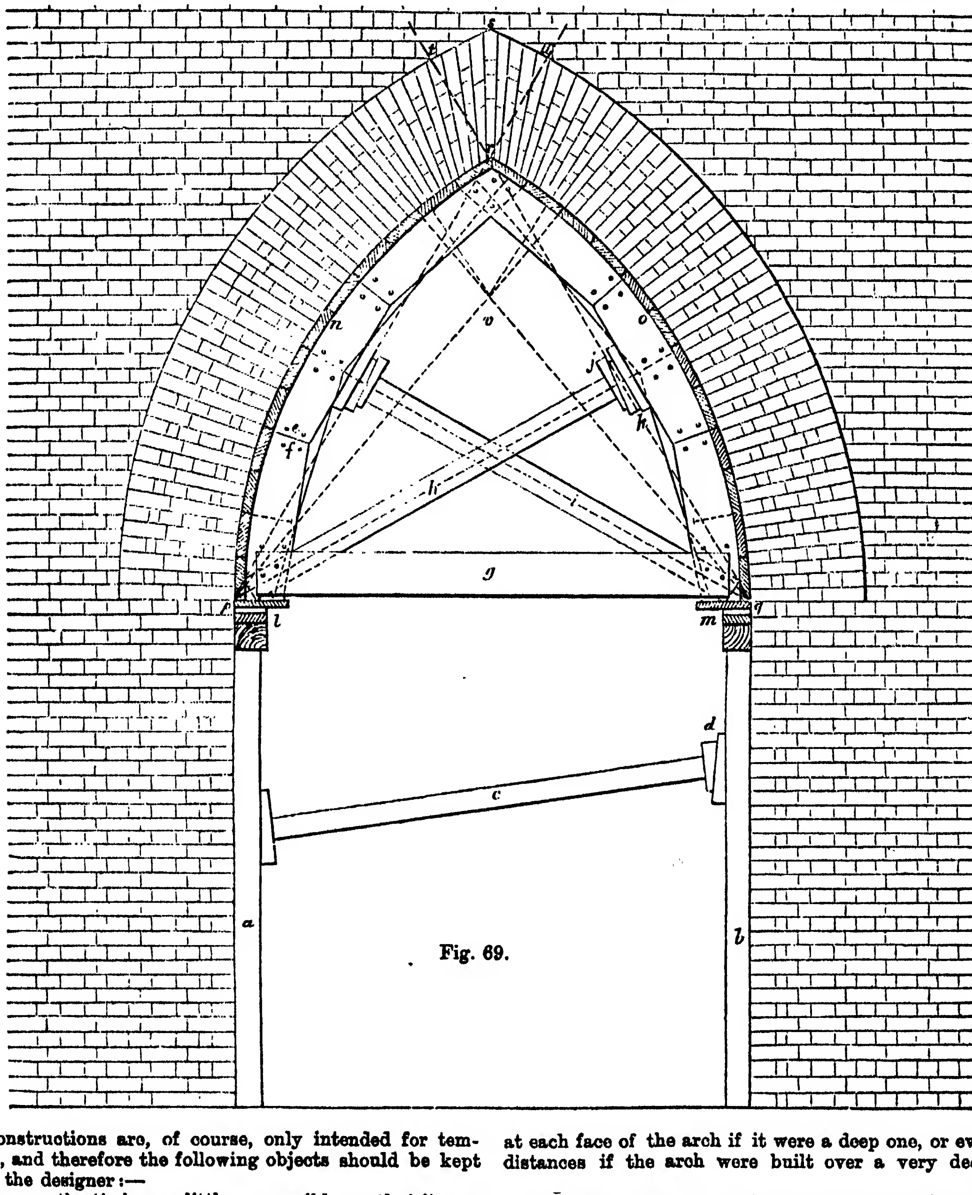


Fig. 69.

These constructions are, of course, only intended for temporary use, and therefore the following objects should be kept in view by the designer:—

1. To damage the timber as little as possible, so that it may be used again when required. Of course, this condition must yield to the necessity of the case; but in all works *proper* economy (provided it do not degenerate into a "penny wise and pound foolish" system) is an element which must never be neglected.

2. That the design of the centering must be such as to resist any strain which may cause alteration of form during the building of the arch; and

3. That arrangements should be made that the centering can be *eased* or lowered *gradually*, in order that any settlement of the arch which may take place, owing to the support being removed, may not be sudden; for if the support were at once withdrawn, the arch might settle in one part more than in another, and the whole work might in consequence give way or be permanently injured.

In Fig. 68 we find an exceedingly simple centering.

The walls A B, C D having been raised, the centering is erected. This consists of five sticks of timber, E, F, G, H, I, kept in their places by the cross-struts J K. These posts would be placed at each face of the arch if it were a deep one, or even at closer distances if the arch were built over a very deep vault or

Cross-wise, resting on these uprights, are laid horizontals, the ends of which, L M N O P, are shown in the illustration; and on these again planking is placed, on which the arch would be built. An important feature, however, is that mentioned under the third heading—namely, the arrangement which must be made so that the centering may be eased gradually before absolute removal.

Fig. 68 shows the most simple method of doing this. It will be seen that each support rests on two wedges mutually opposed, as Q, R, etc. Now, it will be evident that by striking each in turn, the whole of the wooden structure will sink almost

imperceptibly, and thus allow the arch to come to an equal settlement throughout, and then the whole framing may be removed.

After the preceding observations on centering, we now return to the brickwork of the subject under consideration.

It will be seen in Fig. 68 that the greater portion of the weight of the superstructure is borne by the upper arch, which is hence called the *relieving* arch. That this is necessary will be evident when it is remembered that all the support gained from the apparently broad straight arch was that derived from the arch of the width S T, or about one brick.

The relieving arch, struck from the same centre as that to which the skew-backs of the straight arch converge, thus bears the main burden; and its purpose is further enhanced by a tension rod, U V —viz., a rod of iron passing from the intrados of the flat, to the extrados of the relieving arch, by reason of which the sinking of the former is rendered impossible, owing to its being suspended, as it were, from the latter.

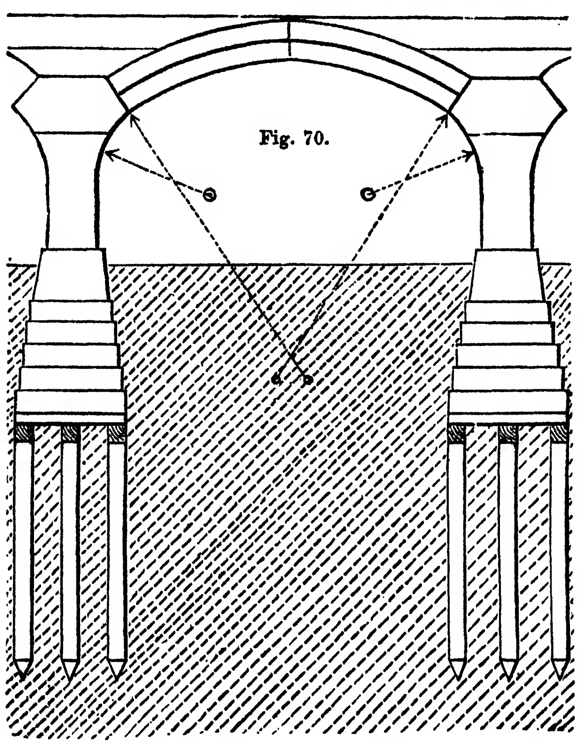


Fig. 70.

Fig. 69 represents a Gothic or pointed arch, constructed of bricks. Here another very simple form of centering is shown. It will be seen that the posts *a* and *b* are placed against the piers, and are kept separate by the cross-strut *c*, the force of which may be gradually diminished by striking the wedges at *d*. On these posts rests the true centering, which, it will be seen, is formed of pieces of timber placed in the manner called "break-joint" —that is, of two thicknesses timber, so united that the joints of the one side, *e f*, are covered by the whole wood on the other; and this mould again is supported by, first, a cross-piece, *g*, at the springing, and then by cross-struts, *h*, *i*, which can be relieved or eased by the wedges at *j* and *k*, as can also the centering by those at *l* and *m*. The several centres, or trusses, which may be required for the depth of the arch, are united by timber laid cross-wise, the ends of which are shown at *n* and *o*, etc.

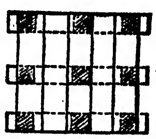


Fig. 71.

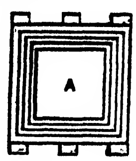


Fig. 72.

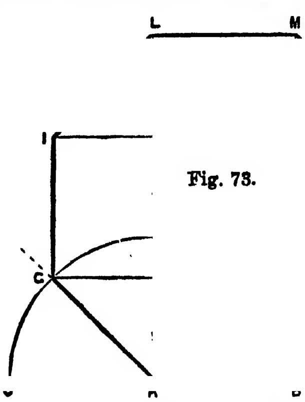


Fig. 73.

The curves of the arch are, of course, struck from the imposts, this being an equilateral arch. The intrados and extrados having therefore been drawn, divide the latter into the number of bricks required.

Now the majority of the radii are drawn to the centres from which the arcs *p*, *q* are struck; but it will be seen that if this system were continued, the entire mass of bricks forming the block *r s t u* would not be influenced by such convergence, for the bricks would have to be cut so as to meet in the centre line, and would thus have no influence as a keystone unless a heavy weight were placed over it to keep it down, without which the pressure on each side would tend to force it upward and out of its place. When, therefore, these radii have reached about 50° on each side, and intersect in *v*, this point must be constituted a new centre, and all radii between *s t* and *s u* must be drawn to it.

DRAWING FOR MASONS.

Fig. 70 is an example of planking, brick footings, and stone piers, as adopted in the circular vaulting at the London Docks.

The foundation consists, in the first place, of nine fir piles 9 inches square, disposed as in the plan (Fig. 71). On these rest, first, three fir-sleepers, also 9 inches square, and across these fir-planking 6 inches thick, forming a platform 4 feet 10½ inches square. On this rests the mass of brickwork in five ranges, 11½ inches high, consisting of four courses (Fig. 72). The footings are 2¼ inches all round, thus making each range 4½ inches smaller across than that on which it rests. The surface of the brick foundation at A is therefore 3 feet 4½ inches.

The base of the pier, which stands on the brickwork, is of stone taken from Bramley Fall Quarry. This base is 3 feet square at the bottom, and 2 feet 4 inches at the top; the angles are, however, splayed off, and the upper surface thus becomes an octagon. The shaft, which is of granite, is octagonal, and is 2 feet wide at its lower end, but diminishes to 1 foot 10½ inches at 3 feet high. This may be said to be the springing-point of the arches. The section shows that of a four-centred arch, the centres of which are marked in the drawing.

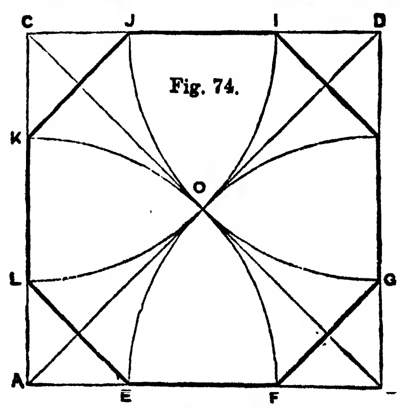


Fig. 74.

The pier widens out at the top, and is surmounted by a cap, or springing stone, also from Bramley Fall Quarry.

It has just been remarked that the upper surface of the base of the pier described above becomes an octagon when the angles at the corners are splayed off. As a useful exercise in Geometry and Linear Drawing which bears immediately on this part of our subject, we will add two problems: (1) on the construction of a regular octagon on a given line, and (2) the inscription of an octagon in a square. It is the second of these problems which is brought into practice in taking off the angles

of the block, so that, when this is done, the upper surface may present the form of a regular octagon.

To construct a regular octagon on the given line A B (Fig. 73).—Produce A B on each side. Erect perpendiculars at A and B. From A and B, with radius A B, describe the quadrants C D and E F. Bisect these quadrants, then A G and B H will be two more sides of the octagon. At H and G draw perpendiculars, G I and H K, equal to A B. Draw G H and I K. Make the perpendiculars A and B equal to G H or I K—viz., A L and B M. Draw I L, L M, and M K, which will complete the octagon.

To inscribe an octagon in the square A B D C (Fig. 74).—Draw diagonals, A D and C B, intersecting each other in O. From A, B, C, and D, with radius equal to A O, describe quadrants cutting the sides of the square in E, F, G, H, I, J, K, L. Join these points, and an octagon will be inscribed in the square.

PROJECTION.—XIII.

QUESTIONS FOR EXAMINATION (*continued*).

82. There is a solid cross, formed by a central cube of 1 inch side, on each face of which another similar cube is fixed. Give the plan and elevation when two vertical faces of the original cube are parallel to the vertical plane.

83. Draw the plan and elevation when of the two adjacent vertical sides of the original cube one is at 60° and the other at 30° to the vertical plane.

84. Project this object when resting on one angle of the base of the lowest cube, which is inclined at 30° to the horizontal plane, the diagonal being parallel to the vertical plane.

85. A cone, the base of which is 4 inches and the altitude of which is 5 inches, is penetrated by a cylinder of 2 inches diameter. The axis of the cylinder intersects that of the cone at right angles, at 1 inch from the ground. Draw plan and elevation when axis of cylinder is parallel to vertical plane.

86. Project this object when the axis of the cylinder is at 60° to the vertical plane.

87. A cone of 3 inches diameter, the height of which is 3½, rests on a cube of 3 inches side. Give plan and elevation when sides of cube are 50° and 40° to vertical plane.

88. Project the front view of the group when the one diagonal of the base is parallel and the other at 35° to the horizontal plane.

89. There is a cube of 3 inches side, on which rests a cylinder of 2 inches diameter and 3 inches high. This supports a cone of 3 inches diameter and 2½ inches high, the axes of all being coincident. Give the front elevation of the group, when resting in a plane inclined at 25°. The other conditions at pleasure.

90. There is a solid formed of two equal square pyramids of 2 inches base and 3 inches altitude, which are united by their bases. Draw the elevation and plan when the object rests on one of the triangular faces of one of the pyramids, the axis of the object being parallel to the vertical plane.

91. Give the projection of the object, when resting on one of the faces of one of the pyramids. The axis is at 45° to the vertical plane.

92. Draw the elevation and plan when the object rests on an *edge* of one of the pyramids, the axis being at 60° to the vertical plane.

93. Construct an isometrical scale of $\frac{1}{15}$ of an inch to the foot. Show 20 feet.

94. Draw an isometrical projection of a plane square of 2 inches side.

95. Give an isometrical projection of a pavement consisting of squares of 1 foot side. Scale, ½ inch. Show 5 squares in width and 12 in length.

96. Draw an isometrical projection of a cube of 2 inches edge.

97. Draw the isometrical projection of a box 3 feet square and 2 feet high, made of wood 3 inches thick. Scale, 1 inch to the foot.

98. There is a block of stone, 6 feet square and 1 foot high; on this rests another, of the same height and 4 feet square; and on this again a third block, of the same height and 2 feet square, is placed, the centres of the three blocks being over each other. Give the isometrical view of the group. Scale, ½ inch to the foot.

99. A cylinder of two inches diameter and 4 inches long lies so that its end is vertical. Give the isometrical projection.

100. There is a stool the top of which is a square of 12 inches side, the height 18 inches, and the thickness of the legs 2 inches (the other measurements at pleasure). Scale, 2 inches to a foot. Draw an isometrical view of this object.

⁂ It is obvious that no Key to the foregoing Exercises in Projection can be given. Each proposition must be worked out by means of drawing, and our space is too limited to do this even on a very small scale.

AGRICULTURAL CHEMISTRY.—VI.

BY SIR CHARLES A. CAMERON, M.D., PH.D.

CHAPTER VI.—ON THE IMPROVEMENT OF SOILS.

We have shown in the last chapter that the fertility of soils is in general but little influenced by the arts of man. As a general rule, a bad soil always remains inferior to that which is naturally fertile. It is, however, possible to greatly improve the capabilities of inferior land; and, as we have seen, fertile soils go out of condition where their cultivation is not properly attended to.

Some soils are too light; they do not afford adequate mechanical support to the plant, and they do not retain sufficient moisture. On the other hand, there are clays so very adhesive, that it is almost impossible to render them sufficiently porous to allow that circulation of air and water through the soil, without which plants cannot be perfectly matured. It is evident that the act of commingling a light soil with a heavy clay would produce a mixture greatly superior to either when separate. A stiff clay may fail to produce good crops, whilst the light drifting sands—perchance not far distant—are scarcely clothed with any kind of vegetation. The combination of the two would in all probability produce a productive soil. This reasoning is very sound in theory, and sometimes it admits of being practically applied; but occasionally the operation of mixing soils is found to be a most expensive one. When the two classes of soils are close to each other, it is very probable—nay, almost certain—that their admixture could be economically effected. It is a much more common practice to improve light lands by the addition of sand or gravel to them; but it is rather rarely that stiff clays are ameliorated by the addition to them of sand, though there appears to be no good reason why such should not be the case.

Bogs and peaty soils are often barren because they contain excessive amounts of organic matter; they would consequently be greatly improved by the addition of marly clays. The defective ingredients of peaty soils—alumina and lime—are abundantly present in marly clays. Light lands are often greatly improved by folding sheep upon them. The tramping of the animals consolidates the soil, and their *excreta* enrich it and render it more coherent. Bulky fertilisers are best applied to stiff clays, and well-fermented and dense manures to light soils.

Warping soils means to manure them with mud. The annual overflowing of the Nile covers the fields of Egypt with a fine mud, which possesses wonderful fertilising properties. In some parts of England, lands adjoining tidal rivers are periodically inundated during the influx of the tide, and the excess of water allowed to flow off with the ebbing waters of the river. In this way the surface of the land acquires a coating of silt or mud, often to the depth of several inches, and even feet. Herapath found that the quantity of phosphoric acid deposited by warping on the surface of a certain field amounted to 17,000 pounds, whilst from the same field a crop of wheat abstracted only 53 pounds of that compound.

The beneficial action of quick or burnt lime on soils has been known from a very early period in the history of husbandry. The younger Pliny mentions that marl and lime were largely employed by the agriculturists of Gaul and Britain, and Theophrastus and Columella speak of lime as an article in common use amongst the farmers of their days.

Limestone consists essentially of a compound termed calcic carbonate, which is composed of carbonic dioxide, oxygen, and the metal calcium. When heated very intensely, the carbonic dioxide flies off in a gaseous form, and the oxygen and calcium remain as a white earth, termed calcic oxide, or calcic anhydride. When water is poured on calcic anhydride (quick or

caustic lime), the two substances unite and form calcic hydride (slaked lime, formerly termed hydrate of lime). During the slaking of lime heat is evolved, and the hard stone crumbles into a fine powder. If an excess of water be used, a semi-liquid results, termed cream or milk of lime, according to its consistency.

In the soil lime acts chemically and physically, and it also contributes directly to the nutrition of plants. As a mere mechanical agent, it has proved most useful in rendering stiff clays less tenacious, and more porous and pervious. Many heavy clays, which can only be properly cultivated by great labour and expense, might be rendered friable, and easily workable, by a liberal application of lime. Dense, adhesive clays do not readily admit the permeation of air through them; therefore any mechanical agent—such, for example, as lime—which renders them more open, indirectly contributes to their chemical improvement, because the active circulation of air throughout the soil produces abundance of plant-food, as we have shown in previous chapter.

As lime, though not so dense as heavy clay, is more compact than sands, the latter are improved by a dressing of marl—a substance very rich in lime. In the case of clays and sands, no apprehension of injury from over-liming need be apprehended, provided that the lime be applied chiefly in the form of marl or chalk; for enormous quantities of quicklime act corrosively upon vegetables and their seeds. The best wheat soils in Middlesex contain 10 per cent. of calcic carbonate, and in many of the most fertile grass-lands in Ireland more than 20 per cent. of this substance exists; whilst some of the soils of Somersetshire—famous for their cheese-producing capabilities—contain about 70 per cent. of lime compounds. In the use of lime as a mechanical agent the chief point to consider is, Will it render the soil too light? In the case of green crops there is little danger of the soil being too light; but when oats and other cereals are cultivated, it sometimes happens that over-doses of lime are applied. In such cases—even if the soil be old lea or grass-land—the plants may braird satisfactorily, but they will hardly produce seeds, and will generally perish about June. The cereals require a moderately stiff soil to sustain their slender roots, and if such support be denied they rarely vegetate vigorously. Land rendered too porous by over-liming is improved by growing turnips on it, and allowing sheep to feed upon the crop in the field. The soil may also be consolidated by means of heavy rollers passed over it. It is a curious fact, that land, injuriously affected by over-liming, may yet be in want of lime. This arises from the circumstance that lime sinks very rapidly from the upper 4 or 5 inches of surface-soil; and although the whole soil may have been rendered too loose by former calcareous applications, yet the part of it from which the nutriment of the crop is chiefly derived may be deficient in lime. In cases of this kind, lime should be applied in the form of a heavy compost. Road-scrapings are often found a useful application to land suffering from the physical effect of over-liming, but which is in actual want of calcareous matter.

The chemical action of lime upon soils is most important. Burnt lime, chalk, and marl combine with, and render innocuous, various hurtful acids which occasionally occur in soils, but more especially in undrained lands. Farmers well know that lime *sweetens* (to use their own term) their lands, and that it produces on meadows and pastures sweet and nutritious herbage.

Quicklime acts chemically upon some of the rocky parts of soils, and hastens their disintegration or decay; in this way lime liberates a portion of the fertilising matter contained in the coarser portion of the soils.

Every fertile soil contains a large amount of organic matter, formed chiefly from plants and parts of vegetables more or less decayed. During the decomposition of the organic matter (*humus*, or mould) its constituents enter into new combinations, and ultimately pass into their original mineral condition of carbonic dioxide, water, and ammonia, and earthy and saline matters. The perfect decay of organic matter only takes place when air is present; and hence the more porous a soil is, the more quickly does its *humus* decay, because there is an abundant circulation of air in the soil. Quicklime also hastens the decomposition of organic matters, converting their nitrogen (combined with a portion of their oxygen) into nitric anhydride, which, uniting with lime, produces calcic nitrate (nitrate of lime)—a valuable source of nitrogen to plants. When soils contain an excessive proportion of organic matter, they are greatly benefited by an abundant application of lime. A single "dressing" of lime to an unproductive bog or peaty moss often produces a fine and spontaneous crop of white clover.

Limestone, gravel, marls, and shell and coral sand owe their efficacy almost wholly to the calcic carbonate which they contain. They neutralise the sour liquids in undrained and boggy soils, and they supply lime to the crops. Shell and coral sands are well adapted to poor heathy lands; limestone-gravel is an excellent agent in the reclamation of bogs. Marls and chalk have a wide application, and may be always used wherever the soil is deficient in lime. Limestone containing a small proportion of magnesia may be employed in agriculture; but dolomite, or magnesian limestone, should not be used, for when burned and slaked its hydrate forms a hard mass instead of a powder.

Quicklime exposed to the air absorbs—but very slowly—the atmospheric carbonic dioxide, and in part becomes calcic carbonate—a compound which on the whole is not nearly so useful in agriculture as burnt lime. The sooner lime is used after it comes from the kiln the better; and its conversion into calcic carbonate should be impeded by preserving it in large heaps. A thin layer of quicklime soon loses its caustic properties.

The quantity of lime applied as a prime "dressing" per statute acre varies; the longer the land has been without a liming, the greater is the quantity of lime which it requires. For medium and stiff soils 150 bushels are probably the minimum, and 300 bushels the maximum, quantity with which the best results may be effected. In the case of light lands 70 or 80 bushels will in general suffice. Wet land requires more lime to produce a given effect than is necessary in the case of wet soils; and here we have another instance of the many economical results of drainage. When the soil has been well limed it will, as a rule, be benefited by a moderate application of the earth once during each rotation of crops.

The processes of "paring" and "burning," at one time considered to be in almost every case injurious, are now admitted by scientific agriculturists to be often very useful, when properly carried out. Good soils seldom contain more than 10 per cent. of organic matter; but bogs often include 95 per cent. (excluding water) of partially decomposed vegetable matter, and only 5 per cent. of mineral matter. When bogs do not furnish fuel (turf or peat), or when that part of them which is generally used as fuel has been exhausted, their excess of organic matter is sometimes best got rid of by burning it. In general the combustion should be allowed to extend downwards to the depth of from 3 to 7 or 8 feet. The less mineral matter contained in the peat, the greater is the quantity necessary to be burned in order to obtain a sufficient quantity of ashes to mix with the unburned turf. Marshy land, and soils containing mosses and other weeds and coarse herbage, are improved by burning their surface; the weeds and their seeds are thereby destroyed, and their ashes increase the fertility of the soil. Burning is sometimes one of four processes employed in the reclamation of bogs; the others being drainage, liming, and the application of sand or clay.

A common defect of clays is their extreme plasticity and adhesiveness. Their particles lie so closely together that air and water cannot freely circulate amongst them. If we subjected a piece of clay to intense heat, it would assume a glassy or slag-like condition; but if we heated it moderately, it would only become a dry, porous, and friable mass. Now, by burning heaps of weed, cinders, or coal-dust on clays (selecting very dry weather for the operation), we can greatly improve their texture, and increase their productive capacity. After such an operation the air gains access to the interior of the soil, and prepares from its rocky particles the fine fertilising powder which, as we have already stated, is the chief source of the ash, or inorganic constituents, of plants.

TECHNICAL DRAWING.—XIX.

DRAWING FOR MACHINISTS AND ENGINEERS.

MECHANICAL DRAWING.

Fig. 202 is a drawing of a simple fly-wheel of a winch.

Draw the circles A and B for the outer and inner edge of rim.

Divide the circle B into six equal parts, and draw the d meters C D, E H, G F, or radii C, E, F, D, H, G.

Next draw the circles I and J, and also the circle *i*, the edge of the boss being bevelled.

A portion of the inner circle, representing the end of the shaft, is then to be slightly flattened, and the key by which the wheel is fastened is to be added.

To find the points from which the arcs are to start from the straight lines, describe a circle passing through N O, cutting the sides of the other five arms in the required points.

Similarly, the arms at their base are united by an arc, which, in a subject as small as this, may be struck with any convenient

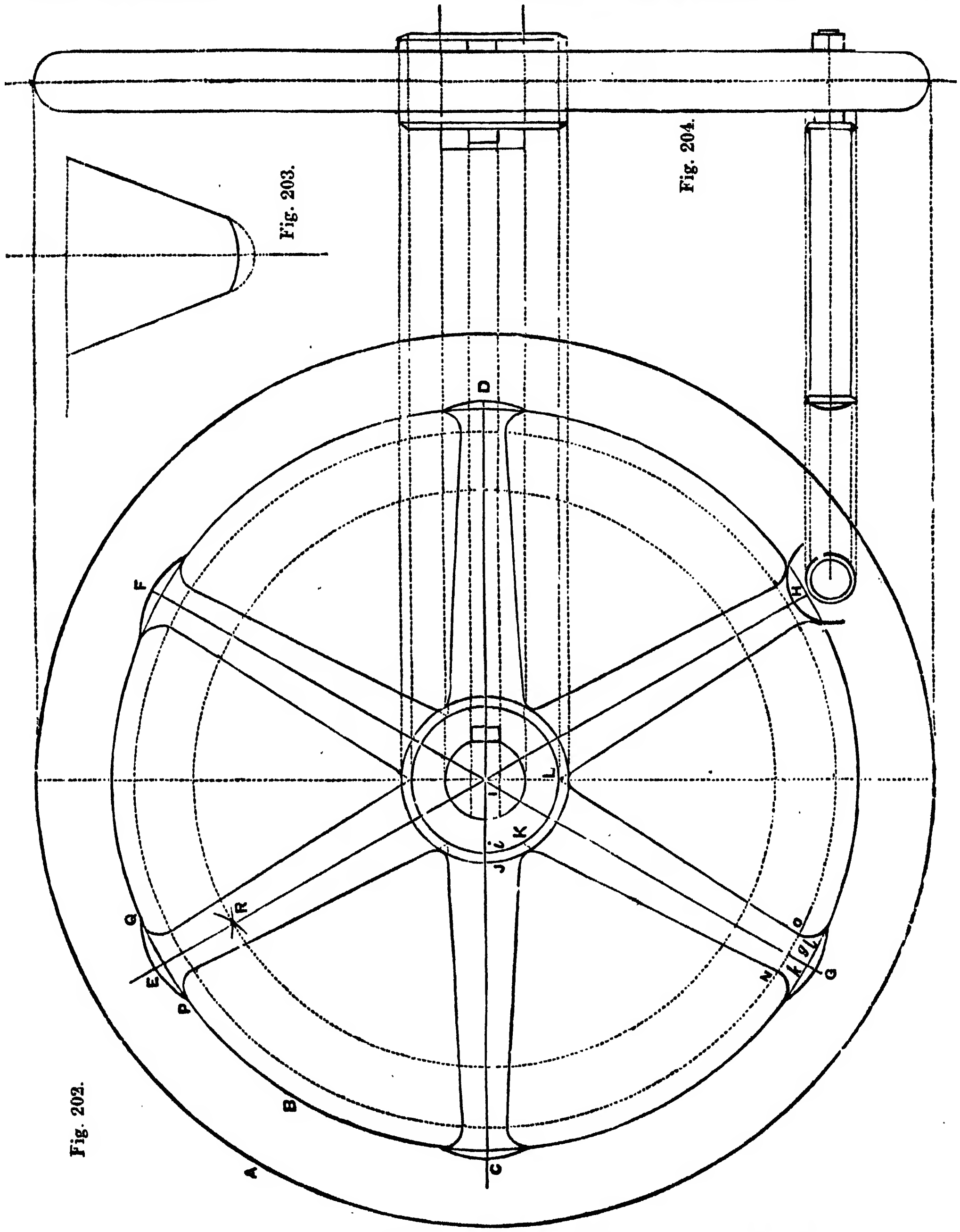


Fig. 202.

Fig. 203.

Fig. 204.

Midway between the radii, on the circle *i*, set off the points K and L for the width of the inner ends of the arms.

On each side of the radii set off on the circle B, *g k*, *g l* for the width of the arms at their outer end.

Draw K *k* and L *l*, and repeat the process on each of the radii.

The arms do not, however, meet the rim in a sharp point, but the straight lines are joined to the circle by means of a small arc, shown at N and O. These arcs are to be drawn as already shown in Figs. 180 and 181.

radius from some point on the line bisecting the angle. In a drawing on a larger scale, the arc would be drawn by the method shown in Fig. 200.

These curves should not again form angles at the points where they meet the straight lines, which would be the case if drawn too flat, as in Fig. 203. The arcs should be so drawn that the curve merges imperceptibly into the straight lines, as shown by the dotted portion.

From one of the points in which the radii cut the circle B, as E, set off the distance E P, E Q.

From P and Q set off the length P Q on the radii, and from P and Q, with radius P Q, describe arcs cutting each other in R, and from this the arc P Q may be struck, representing the curve formed by the arm meeting the rim, which is rounded off to a semi-circular section at its inner and outer edges, as will be seen in the edge elevation (Fig. 204). This last is projected from Fig. 202, and should be drawn upon a centre line, whilst the centre line for the handle is drawn from the centre of the end of the handle.

Fig. 205 is a geometrical elevation of a V-threaded screw, as rendered in mechanical drawings in the general course of business. This is entirely a conventional method, generally used in the elevation of a cylinder such as would remain if the thread of the screw were turned completely off. This is called the *inner* cylinder. Again, the perpendiculars B and C give the elevation of a cylinder which would just contain the screw; this is called the *outer* cylinder.

Now set off on the central perpendicular a number of divisions equal to half the width of the thread—viz., F, G, H, I, J, etc.

Through these points draw oblique parallel lines, taking care that their inclination is not too much to be inconsistent with the pitch of the screw, of which more will be said in another lesson.

These oblique lines are to extend alternately across the inner

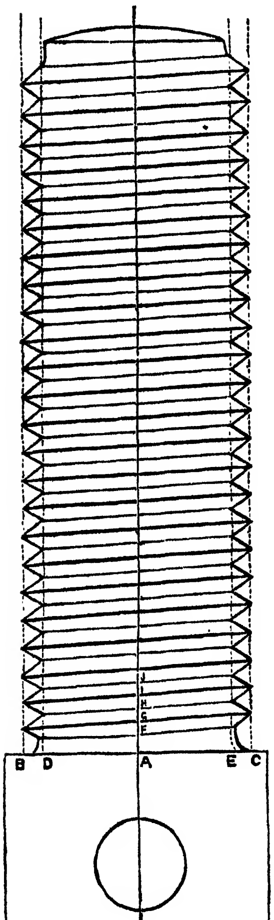


Fig. 205.

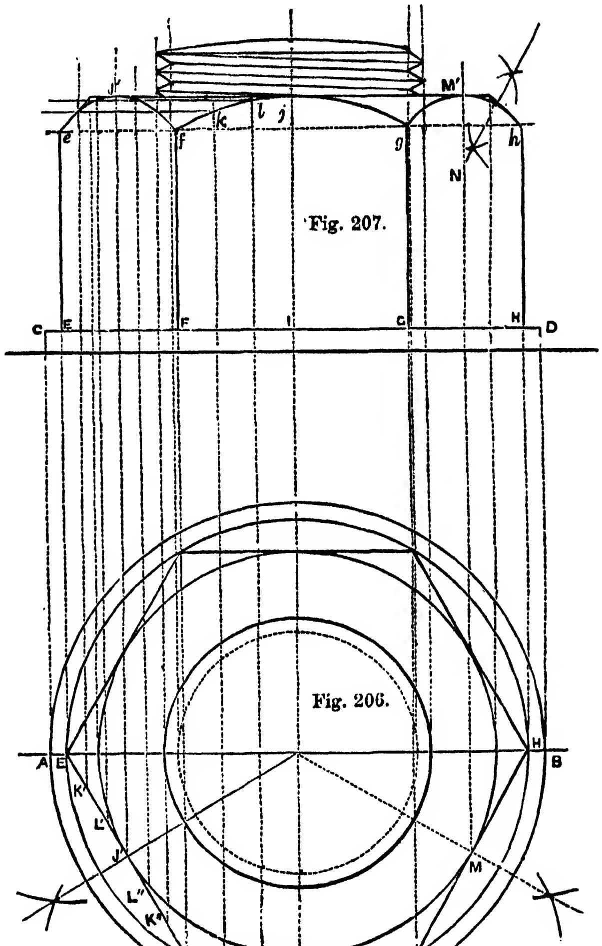


Fig. 207.

Fig. 206.

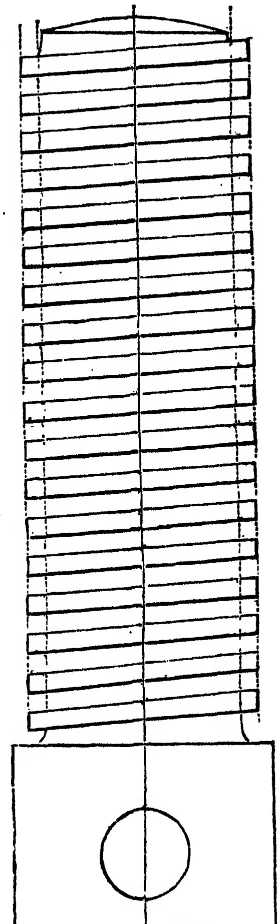


Fig. 208.

Mechanical Drawing, for, in reality, the line which forms the thread of a screw is one which, in ascending, winds round a cylinder, and is termed the *helix*. The rapid method shown in this figure is, however, found so very useful that it is thought desirable to make the student acquainted with it in this place, in order that he may be able to draw subjects in which the screw may be introduced; but the correct method of projecting screws will be worked out further on.

Draw a central perpendicular, and at the base construct the rectangle representing the head of the screw, the curve at the bottom being struck from a point on the centre line.

On each side of A set off half the diameter of the screw—viz., A B and A C, and draw perpendiculars from these points.

Next set off from A, A D and A E, and erect perpendiculars from these points also. The perpendiculars D and E will give and the outer cylinders, and the angle of the thread is formed by joining their extremities.

The mode of starting the screw at the head and of terminating it at the end, etc., will be understood from the example without further remarks.

Figs. 206, 207.—The subject of this study is a hexagonal nut, showing also the end of the screw and washer.

Having drawn the plan (Fig. 206), project the circular washer from the diameter A B, and draw the horizontal C D (Fig. 207) at the proper height.

It will be seen that the nut is a portion of a hexagonal prism. The full working out of the projection of prisms has been given in the lessons in "Projection."

Next project the perpendiculars E *e*, F *f*, G *g*, and H *h* from the points E, F, G, and H on the plan.

From I (Fig. 207), with radius I j, describe the arc $f\,g$, which will give the curved edge of the face of the nut, which is parallel with the vertical plane of projection.

This arc, of course, is the same on each of the faces; but does not appear so on the other two which stand at angles to the plane of projection. It is therefore necessary to find points through which to draw the curve as it appears.

Divide one-half of the line F G in the plan—viz., F J—into any number of equal parts, as K, L, etc., and from these points erect perpendiculars, cutting the arc $f\,j$ in k and l.

Now divide the side represented by E F in the plan into double the number of parts marked on F J—viz., K′, L′, J′, L″, K″, and from these points raise perpendiculars.

Draw horizontals from j, l, k, cutting the perpendiculars, and through these intersections the curve is to be traced.

In common practice it is usual, however, to draw this curve with the compasses, which may be executed in the following manner:—

Draw a perpendicular from M in the plan to cut a horizontal drawn at j in M′; then find a centre for a circle to pass through g, M′, and h—viz , N. Then from N, with radius N g, an arc used as a rapidly-executed substitute for the curve $\acute{e}\,j'\,f$ can be drawn.

The screw is to be drawn as shown in the last figure.

Fig. 208 is a conventional representation of a square-threaded screw, as commonly used in practice. It must, however, be distinctly understood that this method, like that shown in Fig. 205, is only admissible in drawings on a small scale.

The method of drawing this figure is, in the first instance, precisely similar to that employed in the V-threaded screw; the oblique lines, however, are all drawn across the outer cylinder, and the alternate pairs united.

SEATS OF INDUSTRY.—IV.

By H. R. Fox Bourne.

MANCHESTER AND ITS SUBURBS: THEIR MINOR INDUSTRIES.

To the cotton manufacture of the Manchester district all its other trades are subordinate, yet many of these are very important, and conduce greatly to the welfare of the locality and the whole country.

Chief of these are the hardware trades by which suitable machinery is supplied for the working-up of cotton. Manchester, indeed, vies with Birmingham in the more polished and delicate branches of iron manufacture. In its neighbourhood are some of the largest and most skilful machine-shops in the world, and the demand for tools, which has caused great tool-making establishments to be there set up, has at length made Manchester a centre of iron-trade with far-off regions and in all varieties of iron-ware. Manchester had, in 1860, 48 iron foundries and 63 machinists' shops, giving employment to about 12,000 workpeople, while some 60,000 persons were employed in its 95 cotton mills, and it had, besides, 13 silk mills, with about 2,000 labourers, and 16 small-ware mills, giving employment to nearly as many. Those figures fairly indicate the relative value of the principal industries, not only of Manchester itself, but of all the district round about. Everywhere cotton is chief, but silk and wool are also worked up, and in greater proportion as we pass from Manchester in the direction of the woollen province of Yorkshire or the silken province of Derbyshire; and everywhere engineers are at work constructing mills and tools for the textile manufactures.

No better representative of this iron industry can be found than the Fairbairn Engineering Company in Ancoats. The veteran engineer whose name it bears was, indeed, to some extent the father of the whole trade. "When I first entered this city," he said of Manchester in 1816, "the whole of the machinery was executed by hand. There were neither planing, slotting, nor shaping machines, and, with the exception of very imperfect lathes and a few drills, the preparatory operations of construction were effected entirely by the hands of the workmen. Now everything is done by machine-tools, with a degree of accuracy which the unaided hand could never accomplish. The automaton, or self-acting machine-tool, has within itself an almost creative power—in fact, so great are its powers of adaptation that there is no operation of the human hand that it does not imitate." In working out that change, Sir William Fairbairn himself did much. He had mastered his trade in London and elsewhere, before at the age of twenty-four he settled in Manchester as a working millwright. In 1817 he entered into partnership with a shopmate, James Lillie, and they began a small business of their own. Paying 12s. a week for a small shed, in which they set up a lathe of their own construction, they did various odd jobs until more important work came in their way. They had not long to wait for that. A large commission for mill-work from Adam Murray, a great cotton-spinner, was so well executed that other commissions became plentiful. Sir W. Fairbairn led the way in many of the improvements in mill-work and machine-making that have been effected during the last half century; and where he was not himself the inventor, he succeeded in giving full effect to the inventions of others. He came to be not only the chief engineer and machinist for the Manchester cotton industries, but a great iron-worker for all the world. He was one of the first to develop iron ship-building in 1829, and there are few branches of the iron trade in which he was not engaged. His help to the cotton-spinners, however, was sufficiently important. "In 1815," he said, a few years ago, "the shafts of our cotton-mills were moving at 40 or 50 revolutions a minute, whereas at the present day we have as many as 300 and 350. The same number of revolutions are applicable, and now in use, for lace and silk. The extensive employment of wrought-iron for shafts and the slide-lathe has given wonderful facilities to the production of shafts for increased velocities, with reduced friction, by the transmission of great power through a comparatively small section. In some of the more recent mills of my construction we have shafts only two and a-half inches in diameter conveying the power of a 40-horse engine." It was by that sort of work—by making strong, yet light and slender iron do the duty formerly assigned to clumsy wood, and by carefully fitting all the parts together, so as to receive as much power and as little waste as possible—that Sir W. Fairbairn helped to bring about a revolution in all varieties of mill-work. The large establishment which still bears his name now comprises five great divisions. There is a foundry and forge, provided with steam-hammers, for wrought-iron. There is a boiler-yard, with machinery for rivet-making, shearing, and punching, and a bridge-yard, with similar appliances; there is a millwrights' department, stocked with blacksmiths' forges, turning, planing, and fitting shops; and there is an engine department, able to produce steam-engines of every size and variety required.

Establishments like that of the Fairbairn Engineering Company abound in Manchester and all the adjoining districts. Some adhere more closely to Sir W. Fairbairn's original project, and confine themselves to millwrights' work. Others help the cotton-trade by other kinds of metal-handling. Here, a great factory is devoted to the construction of weavers' tools. There, the work done is chiefly limited to the making of steam-engines. There, again, it may be, only the rough iron-work for railways is done. But everywhere the grand motive is the same—the increasing of facilities for bringing to the Manchester district its great stores of cotton-fibre; for turning it, when there, into cloth; and then for conveying it most promptly and easily to other parts.

The extension of the silk trade to the Manchester district owes its origin to the old habit of blending silk and cotton in one fabric. Macclesfield, seventeen miles south of Manchester, is the chief resort of silk-workers in this neighbourhood. Here the trade has been of very long standing. Although benefited in one direction, it has been damaged in another, by the spread of cotton manufacture. The Macclesfield silk trade was at its height between 1808 and 1825. In 1819 the first silk-mill in Manchester was set up by Mr. Vernon Royle, and in that year it was reckoned that the town contained about 1,000 weavers of mixed silk and cotton goods and 50 workers in pure silk. In 1832 it gave employment, in pure and mixed manufacture, to about 3,600 hands, while the total number of men and women concerned in the trade throughout the Manchester district was nearly 70,000.

The number of other trades, more or less dependent on the cotton manufacture, that have grown up in this great province is legion. "Amongst the textile fabrics," says Mr. Harland, "are those, single and mixed, of woollens, worsted, stuff,

flannel, etc., including blankets; of linen, alone, or mixed with cotton, wool, or silk; velvets, table-cloths, and damasks; counterpanes and quilts; nankeens, jeans, etc.; crapes and bombazines, muslins and mousselines-de-laines, shawls and mantles—in short, every kind and variety of textile fabric is manufactured in Manchester. Amongst more miscellaneous manufactures are those of hats and caps, umbrellas and parasols, india-rubber, gutta-percha, and other waterproof and air-proof fabrics. In copper and brass are various manufactures, especially of rollers for calico-printers, boilers, steps, etc.; in tin, all kinds of wares, including boxes and cases for enclosing goods for hot climates; paper for writing, printing, and packing. In short—including the trades and handicrafts whose produce or productions are in demand everywhere, and those which may be termed the agencies between producer and consumer—there are from six to seven hundred varieties of occupation in Manchester, supplying all the numerous wants of a high material civilisation." Of all that, cotton is the chief cause; but the cotton manufacture could not have attained its vast proportions in this district, but for the proximity of coal and iron with which to work it, and the presence of that perseverance and enterprise which characterises the population as a whole, and has enabled it to send out from its ranks so many men of eminence. Inventors and discoverers—a great number—have arisen in Manchester and its far-reaching suburbs; notable merchants and manufacturers in yet greater number; and not a few skilful statesmen, with Sir Robert Peel at their head.

The eminent Scotch engineer who established the Fairbairn Engineering Company was born in 1789. He was elected President of the British Association in 1860, created a baronet in 1869, and died in 1874. He wrote some valuable works on mills and mill-work, and "Iron, its History and Manufacture."

THE ELECTRIC TELEGRAPH.—V.

OTHER FAULTS—CONTACT—DEFECTIVE EARTH—LIGHTNING GUARDS—MODE OF RENDERING SIGNALS INTELLIGIBLE—SINGLE NEEDLE INSTRUMENT—CODE.

Besides the faults to which we referred in our last paper, there are a few others of common occurrence, the effects of which must be explained in order that we may be able at once to detect them. Perhaps the most common of these is "contact" between two of the wires connecting any two stations. This is sometimes produced by damp weather enabling the current to escape along the surface of the insulators, and is then known as "weather contact." More frequently, however, it arises from one of the wires becoming so slack as to touch against another, or else from some electrical connection being accidentally made between them.

A fault of this kind is very easily recognised. The current leaves the transmitting station, deflecting the needle there as

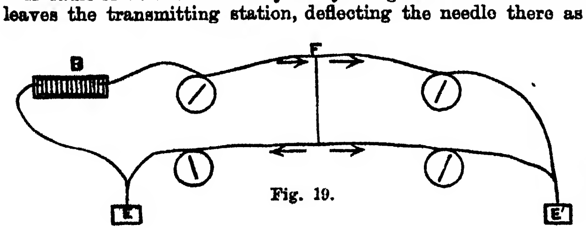


Fig. 19.

usual. At the fault, however (F, Fig. 19), three courses are open for it, and it accordingly divides between them. One portion continues to travel along its own wire, and deflects the needle at the receiving station, but less powerfully than usual, since much of the current has escaped another way; a second portion passes by the place of contact, and returns along the second wire to the sending station, deflecting there the needle of the other circuit, but in the contrary direction; the third portion travels along the same wire to the receiving station, deflecting the second needle there. These effects are more or less modified by the various resistances of the different circuits, still they are so obvious as at once to indicate the nature of the fault.

Another cause of failure is "defective earth" at the receiving station. The communication with the earth-plate is in this case either broken or defective, and a portion of the current accordingly returns by other wires, deflecting their needles in the reverse direction to those in the regular circuit. This fault is liable to be mistaken for contact.

The only other fault we shall refer to is demagnetisation of the needles or other injury to the instrument. The most common cause of such failure is that the lightning has struck the line in some part, and passing along it has injured the instrument. A needle which cannot be demagnetised in this way has been introduced by Mr. Spagnoletti. Its poles are separate blades of soft iron, each magnetised by induction from the pole of an electro-magnet placed near.

Lightning in its effects is found closely to resemble frictional

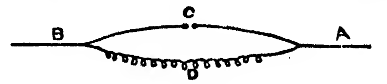


Fig. 20.

electricity. If we have two pieces of wire, A and B (Fig. 20), connected together by a spiral of fine wire, D, and also having connected to them two pieces of wire ending in small balls (C) which nearly touch one another, any galvanic current will pass through the spiral, since it cannot leap across the break between the two balls, however small it be. Frictional electricity would, however, at once take the more direct course, and leap over the small interval at C. This, then, is the principle on which most lightning conductors act, and Fig. 21, which represents Breguet's Lightning Discharger, shows us one mode in which this principle is put into practice.

Two plates of metal cut at the ends into teeth resembling those of an ordinary saw are fixed to a wall, so close to one another that their teeth almost touch. The line-wire, L, is connected with the one of these seen on the left, and the current passes along the plate to the piece of metal *a*, and thence along a piece of fine wire, contained in a glass tube, to the screw *b* and the instrument. Another wire, J, leads from the right-hand plate to the earth, so that if the lightning strikes the line the electric fluid will dart from the points and travel on to the earth by this wire. Should this wire fail to carry off all the current, the thin wire in the glass tube is fused by it, and thus it is prevented entering the instrument-room and injuring the instruments there. The fine wire can, of course, be very easily replaced. The object of the handle seen attached to one plate is that during a storm it can, if required, be turned so as to afford a direct communication between the two plates, and thus cut the instruments for the time entirely out of the circuit. In some forms of lightning protector a thin wire, like that enclosed in the glass tube, is depended upon alone for protection, since any current of electricity like that produced by a flash of lightning would instantly melt this wire, and thus save the instruments. In the protector which we have explained protection is afforded in both ways, and it is therefore doubly safe. Many other forms of lightning discharger are employed, but nearly all act in a similar way, and we need not, therefore, stay to explain the peculiar construction of each.

We have thus seen the way in which the electric current is generated, the manner in which it is conducted from place to place, and the precautions which have to be taken to prevent its escape. We have also seen the nature of the more common interruptions in any electric circuit, and we must therefore pass on to that which is perhaps the most important point of all—the manner in which an electric current may be made to produce intelligible signals at a distant place, and the construction of the instruments that are employed for this purpose.

An electric current is capable of producing many different effects, as we have already seen in our "Lessons on Electricity" in The Popular Educator. It will convert a bar of soft iron into a magnet, or cause a compass needle to point in a different direction; it can be made to decompose water and various chemical substances, or to render a piece of fine wire red-hot, and to produce many other results. Many of these effects are capable of being employed as a means of transmitting our thoughts and messages, and in fact there are few of them that have not so been employed at different times and by various

inventors. The number of instruments that have been introduced is, therefore, very large indeed, and there are many varieties which are still in constant use.

The three effects of the current which have been by far most generally used in telegraphy are—

1. Its power of reversing a magnetised needle.
2. Its power of converting a bar of iron into a magnet.
3. Its power of decomposing various chemical substances.

Perhaps the first is the most simple effect of all, and "needle instruments" which depend upon it are so extremely common that we will take these first, and endeavour fully to understand their construction and action.

The broad principle on which they act was discovered by Oersted, and is simply this—that if an electric current be made to pass along a wire placed near a magnetised needle, that needle, instead of pointing to the north, will point to one side of it; and if the current be made to pass along the wire in the reverse direction, the needle will point to the other side of the north. If, then, we have such a needle at the receiving station, and possess the means of sending at pleasure a positive or a negative current, we can cause this needle to be deflected to the right or left at pleasure, and from these two signals we can form a code by which any letter in the alphabet can be sent.

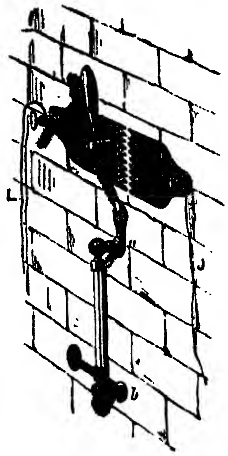


Fig. 21.

In the needle instrument, as in all other kinds of instruments used in telegraphy for the transmission of messages, three distinct parts are necessary: these are (1) the transmitting instrument, (2) the receiving apparatus, and (3) the alarum.

It might be thought that the last-named part is indispensable, but this is not the case, since the click of the needle might call the attention of the clerk in charge to the fact that a message was coming. This is, however, very unsatisfactory, as an important message might be seriously delayed by the clerk not hearing this; an alarum is therefore always employed. It consists of an apparatus by which the current is made to ring a bell in a manner that will hereafter be described. It would, however, be very undesirable that this bell should continue to ring all the time that the message is being received, and an arrangement is therefore made by which it may at pleasure be cut out of the circuit, a more direct path being then provided for the current.

The usual plan is for the circuit, under ordinary circumstances, to be completed through the alarum. As soon as this rings, the clerk, by means of a switch, turns the current from the alarum to the instrument, and receives the message, taking care, when he has received it, to alter the switch again. The alarum is often put in the same case as the instrument, but it is essentially a distinct thing.

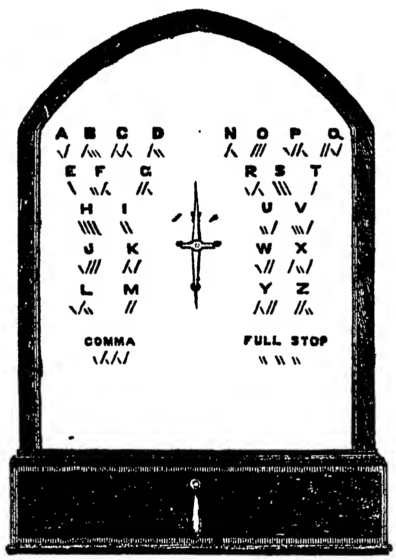


Fig. 22.

The general appearance of the single needle instrument is shown in Fig. 22. In the centre of the dial-plate is seen the needle, the play of which is limited by means of two small pins placed one on each side. The handle in the lower part of the instrument is for the purpose of moving the transmitting apparatus, which is so arranged that when this handle is inclined to the right a current is transmitted along the line in such a direction that all the needles in the circuit are likewise deflected to the right, and when this handle is moved to the left a current is sent in the reverse direction, so that the needles are all deflected to the left. When a motion of the needle in either direction is spoken of, it should be remembered that it is the upper end of the needle that we mean.

The mechanism in the interior of the instrument, by which the current may be sent at will in either direction, will be explained in our next paper. We will here assume that we have the power of sending at pleasure either a positive or a negative current. All the needles along the line of wire will accordingly act simultaneously, and be deflected in the same direction. We possess, then, two distinct signals—viz., an inclination of the needle to the left or a similar inclination to the right. The lower end of the needle is so weighted that as soon as the current ceases it shall return to its original vertical position.

From these two signs, then, we have to construct an alphabet, and this is not a very difficult task, since we can give two or more consecutive beats in either direction, or in alternate directions. No letter is found to require more than four such beats, and by carefully arranging the letters so that those most commonly employed are represented by the simplest signs, we are enabled to send messages with an average of a little more than two inclinations for each letter. A trifling pause is made between each letter, and a somewhat longer one between the words; but after a little practice it is easy to read off messages, even if some of these are omitted.

The code of signals is, of course, purely arbitrary; a standard one has, however, been settled on, and is now almost universally adopted, since great practical inconvenience is found to arise from the use of several independent codes. That originally introduced for the single needle instrument has now almost entirely given way to a universal one, based on that employed with the "Morse" instrument. This latter is seen on the face of the instrument shown in Fig. 22, and will easily be understood from that.

E and T being the letters in most general use, are represented by single beats of the needle to the left and right respectively. A, I, M, and N each require two beats, while all the rest of the alphabet require three or four.

By a few examples we shall very easily learn the meanings of the marks on the instrument face. A is indicated by a beat to the left, immediately followed by one to the right; B by one beat to the right and three to the left. Other letters are more complicated than these—F, for instance, requiring two to the left, one to the right, and then one more to the left. The signs appear at first to be somewhat difficult; but a little practice soon removes this, and enables the operator to receive or transmit messages with considerable speed.

In addition to these signs for letters there are several others which are frequently required, and hence are included in the code. When a word or message is understood, the receiver acknowledges by a single beat to the right; if, on the other hand, he cannot decipher the movements of the needle, he gives a beat to the left, to signify "not understand."

Figures are all represented by five beats, as follows:—

\////	\\///	\\\//	\\\\/	\\\\\	/\\\\	//\\\	///\\	////\	/////
1	2	3	4	5	6	7	8	9	0

and as the signs succeed each other in a regular course they are easily remembered.

The signs of punctuation are represented each by six distinct beats. Those for the comma and full stop are given on the dial-plate, and will be seen to be equivalent to the letters A A A and I I I respectively. A note of interrogation (?) is represented by the signs for U D; inverted commas (" "), by those for A F; a hyphen (-), by B A; an apostrophe ('), by W G; and parentheses ( ), by K K. In each of these cases the beats succeed one another without any pause, and the letters are merely given as an aid to memory.

VEGETABLE COMMERCIAL PRODUCTS.—X.

INDUSTRIAL AND MEDICINAL PLANTS.

I.—TEXTILE PLANTS, OR PLANTS FROM WHICH WE DERIVE CLOTHING AND CORDAGE.

We are indebted to the vegetable kingdom for clothing as well as food. At what time man first discovered the means of forming articles of clothing from the fibre of plants is not known, but the practice is very ancient. It was understood in the time of the Pharaohs, more than 1,600 years before Christ. Flax is thus alluded to in Genesis xli. 42:—"And Pharaoh took off his ring from his hand, and put it upon Joseph's hand, and arrayed him in vestures of fine linen." It is not improbable that flax was cultivated even in pre-historic periods. It formed both the garments and grave-clothes of the inhabitants of ancient Egypt; for the microscope shows that the cere-cloth which envelopes the Egyptian mummies consists of the fibre of flax. We, therefore, place it first on our list of textile plants, as the one of which we have the oldest historic record.

LEAVES AND BUDS OF THE FLAX PLANT.

Common Flax (*Linum usitatissimum*, L.; natural order, *Linaceæ*).—This plant is a smooth fibrous-rooted annual, about two feet high, with sessile, alternate, lanceolate leaves and terminal blue flowers, in corymbose panicles. Ovary globular, five-celled, each cell containing two smooth, oval, brown, and glossy seeds.

Flax has a very remarkable geographical range, thriving in the temperate, sub-tropical, and even tropical regions. It is cultivated not only in the United Kingdom, but in every part of Europe, in Egypt, and in India. Formerly every rural family in England cultivated as much flax as was required for domestic purposes; now the spinning-wheel has been superseded, and both linen and cotton goods are manufactured by steam machinery in the greatest abundance, in every variety of pattern, and with much less time and labour.

To obtain the fibrous or woody tissue of flax, the plants, after flowering, are first pulled up, dried in the sun, collected, and then soaked in water to destroy their green outer bark. This process is called water-retting, the word "retting" being a corruption of rotting. The tough fibres of the stalks are thus set free, are again dried, and then scutched, or beaten with a heavy wooden instrument, which completes their separation. After this they are heckled, or drawn through the combing apparatus, next bleached, and, lastly, handed over to the spinner.

THE HAIRY SEED OF THE COTTON PLANT.

From flax so prepared, coarse linen fabrics are manufactured; but the flax must be heckled several times through much finer combs to render it fit for the manufacture of fine linen, lawn, or lace. Tow consists of the rough and broken fibres detached from the skeins during the combing process. Linen when scraped is termed lint, in which form it is very valuable to the surgeon as a dressing for wounds.

About 1,292,701 cwt. of flax, dressed and undressed, were imported into the United Kingdom in 1886, chiefly from Russia, Egypt, Turkey, Italy, Belgium, and Holland. We also raise flax largely ourselves, especially in Ireland, where it is one of the staple commodities.

Hemp (*Cannabis sativa*, L.; natural order, *Urticaceæ*).—The hemp-plant is a tall, roughish annual, with a stem from five to ten feet in height, and digitate leaves, with five to seven linear-lanceolate, coarsely-toothed leaflets. The flowers are green and inconspicuous, in compound racemes or panicles, and monœcious, that is, the stamens and pistils are in separate flowers on the same plant. The seed is produced in great abundance, and is used for feeding small birds. The fibres of the stem are much longer and stronger than those of flax, and when separated and prepared (in a manner very similar to that adopted with flax, and already described) constitute the hemp of commerce, from which sail-cloth, sacking, and every variety of cordage are manufactured.

The hemp-plant is a native of Persia and of the northern parts of India, whence it has been introduced into Europe, where it is now extensively cultivated, especially in Russia. Like flax, hemp has a very extensive geographical range, growing in almost any country and climate. It thrives admirably in North America and in Africa, and is found both in a wild and cultivated state from Northern Russia to tropical India.

When growing in warm countries the value of the hemp is much diminished, and another quality is developed—it becomes powerfully narcotic, and its leaves, flowers, and stem become covered with a peculiar resinous secretion called *churrus* in India. By the Arabs this resin is called *hashish;* and during the Crusades, men intoxicated purposely with it, called *hashishim*, used to rush into the camp of the Christians to murder and destroy, whence our word *assassin* is derived. Hemp is employed in other forms besides churrus as a narcotic. The whole herb, resinous exudation included, is dried and smoked under the name of *gunyah* or *bhang*, when the larger leaves and capsules only are employed. The Hindoos of British India, and the Bushmen of Southern Africa, smoke these preparations in rude pipes, as we do cigars and tobacco. These pipes are about three inches in length, and are usually made out of the tusk or canine tooth of some animal, perforated quite through, leaving only the enamel. The general effects of tropical hemp on the system, when smoked, are alleviation of pain, great increase of the appetite, and much mental cheerfulness.

From experiments made with churrus, it would seem that the fakeers and other religious devotees of India are indebted to it for their ability to perform some of their wonderful feats. One of these experiments is thus described by Dr. O'Shaughnessy:*—"At two p.m. a grain of the resin of hemp was given to a rheumatic patient; at four p.m. he was very talkative, sang, called loudly for an extra supply of food, and declared himself in perfect health; at six p.m. he was asleep; at eight p.m. insensible, but breathing with perfect regularity, his pulse and skin natural, and the pupils freely contractile on the approach of light. Happening by chance to lift up the patient's arm, to my astonishment I found it remained in the posture in which I placed it. It required but a very brief examination of the limbs to find that the patient had, by the influence of this narcotic, been thrown into that strange and most extraordinary of all nervous conditions, genuine *catalepsy*. We raised him to a sitting posture, and placed his arms and limbs in every imaginable attitude. A waxen figure could not be more pliant or more stationary in each position, no matter how contrary to the natural influence of gravity on the part: to all impressions he was meanwhile almost insensible." Similar results were obtained from experiments on animals. As soon as the influence of the drug ceases, the patient recovers, without having received any injury from its effects.

SECTION OF SEED OF THE COTTON PLANT.

The narcotic hemp of warm climates was, owing to its peculiarities, thought to be another species, but it is now known only to be a variety, and is distinguished as *Cannabis sativa*, variety, *indica*.

The imports of hemp into the United Kingdom in 1886 were 1,209,903 cwt., chiefly from Russia, Hungary, Northern Italy, the Philippine Islands, and British India. The best Hungarian hemp comes from the district of Peterwardein, under the name of Sclavonian hemp. From Italy we receive, in small quantities, a remarkably fine variety, raised by spade culture, called "Italian garden hemp."

* "Popular Economic Botany," by T. C. Archer, page 153.

In addition to sail-cloths and cordage, a coarse brown paper is made from hemp. Oakum consists of tarry hemp, procured by untwisting old worn-out ship ropes, and is a most invaluable substance to the ship's carpenter, who uses it as stuffing with which to stop any leakage in the vessel during the course of the voyage. Seams of timber-built ships are also caulked with oakum.

COTTON WOOL (the woolly covering of the seeds of several species of *Gossypium; natural order, Malvaceæ*). Much uncertainty prevails amongst the best botanists as to the number of species of *Gossypium* which furnish cotton. Linnæus has described five, Lamarck eight, Wildenow ten, and De Candolle admits of thirteen. The cotton of commerce, which consists of the hairs attached to the seeds, and is therefore cellular tissue, appears to be derived mainly from three species, designated as the cotton herb (*Gossypium herbaceum*, L.), the cotton shrub *indicum*), and the cotton tree (*Gossypium arboreum*).

1. COTTON HERB (*Gossypium herbaceum*, L.).—The greatest amount of cotton is derived from this species, which is the best known and most widely spread. It is an annual, and cultivated in the United States, India, China, and many other countries. It grows from three to four feet in height, having sub-cordate, three- to five-lobed, alternate leaves, and pale-yellow flowers resembling those of the mallow; the stamens are monadelphous, or united into one bundle by their filaments, and the pistil has a three-celled ovary.

After the plant has done flowering, a capsule is formed which is surrounded by the calycine and involucral leaves. This capsule grows to about the size of a walnut in its husk, turns brown as it ripens, and then opens, displaying in its three-celled interior a snow-white or yellow down enveloping each of the three seeds lying in each cell; altogether, nine cotton balls may be collected from each capsule, each ball with its enclosed seed being about the size of an ordinary grape.

Chinese Nankin cotton is manufactured from a variety of this plant. The yellowish-brown colour of the nankin is not artificially produced by dyeing, but is the natural colour of the cotton from which it is fabricated.

THE COTTON SHRUB (*Gossypium indicum*, Lamarck).—The cotton shrub is cultivated in India. It closely resembles the former plant in many respects, but it grows from eight to twelve feet high; its flowers change from white to red, and its capsules are ovoid. The cotton shrub is cultivated in all countries where the cotton herb is found. In the West Indies this plant lives from two to three years, in India and Egypt from six to ten; and where the climate is excessively hot, it is usually very long-lived.

3. THE COTTON TREE (*Gossypium arboreum*).—The cotton tree inhabits India, China, Egypt, the coast of Africa, and some places in America. It grows from fifteen to twenty feet high, and its flowers are red. It yields a variety of cotton of a very fine, soft, silky nature, which is used by the Hindoos for making turbans.

The cotton plant is usually cultivated in fields, and treated as an annual. It is grown from seed which is placed in the ground in holes, sufficiently wide apart to allow for the growth of the plant. The plants are carefully tended until they flower, which is usually eighty days from the time of sowing. The flowers, which are handsome, either yellow or red, and not unlike those of the garden hollyhock, are succeeded by capsules, which, when ripe, open, and the cotton-covered seeds in their interior are immediately removed by the cultivator before the wind is able to scatter them. These cotton seeds are then sent to a mill, where by means of a peculiar apparatus called a *gin*, the cotton is separated from them; they are then either kept for sowing again, or as material for the manufacture of oil, and oil-cake for cattle.

Cotton comes to this country in packages called bales. The word *bale* is applicable to any kind of goods packed in cloth and corded with rope. The average weight of each bale is 336 lb.

In 1886 there were imported into the United Kingdom 15,312,900 cwt. of raw cotton valued at £38,128,110, by far the largest quantity coming from the United States of America. This is made into fabrics, and a great part of it is in this shape re-exported; the remainder being retained for home use. In 1868 the quantity of raw cotton imported was 11,857,893 cwt. The substitution of the power-loom for the hand-loom has caused such an amount of prosperity to the cotton trade, that it is now one of the most important branches of our foreign commerce.

In business, foreign cotton is separated into the following varieties:—

North American or United States Cotton.—This is produced in the states of Georgia, South Carolina, Alabama, Mississippi, and Louisiana. The best American cotton, which is, in fact, the best known in the market, is the celebrated Sea-island cotton, which grows on a row of islands situated along the coast of Georgia. The principal ports for the exportation of United States cotton are Charleston, New Orleans, Mobile, and Savannah.

South American Cotton.—This comes into the market from the Brazils, Guiana, Colombia, Venezuela, New Granada, and Peru. Almost all the West India islands, too, produce cotton, and indeed of a superior quality, preferable even to that obtained from the Brazils.

African Cotton.—Excellent cotton is received from the French island of Bourbon; Egyptian cotton has also greatly improved in quality recently, because the crops have been raised from American seed. The best African cotton is, however, grown in Algeria, and is remarkable for the beauty of its colour, the fineness of its silk, the care taken in harvesting the crop, and the good condition in which it appears in the market. The long silk cotton of Algeria partakes at the same time of the character of the long silk staple of Georgia, and the short cottons of Egypt, and approaches in quality the finest Louisiana variety. Algeria is capable—if the necessary encouragement is given—of producing the finest cotton in the world.

East Indian Cotton.—This is very inferior to the North American, although British India, next to America, furnishes the largest quantity. The silk is very short, and not adapted to European machinery, which is framed for working the finer American long cotton. This cotton is raised chiefly for exportation to China. Recently a better staple has been produced in India from American seed, and already a considerable quantity has been exported to England. East Indian cotton comes in little bales, very strongly compressed and corded, which are carried on the backs of camels, or on wagons, to the Ganges, and there received into boats with capacious interiors; these descend the river, and take the cargo to European ships. The East Indian sorts known in commerce are the Bengal, Madras, Bombay, Surat, Siam, and Manila cottons.

Levant Cotton.—This includes all the cotton which is received from ports in European and Asiatic Turkey, as well as from the Morea and the Archipelago. Like that from British India, it is of inferior quality. The principal sorts are the Smyrnian, Syrian, Cyprian, Macedonian, and Persian cottons. Most of the last is consumed in Persia, excepting some small quantities, which go to Russia *viâ* Astracan.

OPTICAL INSTRUMENTS.—IV.

BY SAMUEL

SPECTACLES FOR THE PRESBYOPIC.

IN the normal or emmetropic eye the recession of the near-point commences about the tenth year, and progresses regularly with increasing age. At forty, it lies about 8 inches; at fifty, at from 11 to 12 inches, and so on; and no inconvenience is experienced from this recession till about the age of forty or forty-five. This change in the near-point is met with in all eyes, being also found in the healthy myopic and in the hypermetropic eye, and is due to anomalies of accommodation; while hypermetropia, myopia, and astigmatism are referable to anomalies of refraction (see Figs. 6 to 11, page 160). The question will be asked, When are we to consider an eye presbyopic? Donders has established an arbitrary standard by which he considers we should regard presbyopia to have commenced when the near-point is found to have receded farther than 8 inches. The hypermetropic eye is considered to become presbyopic so soon as, while using glasses which neutralise the hypermetropia, the near-point lies farther from the eye than 8 inches. This standard also holds good in regard to myopic eyes, when the distance of the near-point amounts to more than 8 inches, and it follows that only to slight degrees of myopia can presbyopia in the ordinary sense of the word belong;

where M = $\frac{1}{8}$ it is almost impossible, even with total loss of the power of accommodation. In slight degrees of myopia, presbyopia occurs much later than in the emmetropic eye. Herein the myopic (of $\frac{1}{10}$ to $\frac{1}{14}$) find a compensation for what they lose, in respect to vision of distant objects, and the advantage is not slight, to find that they can, up to the age of sixty or seventy, dispense with spectacles for the observance of such objects as come immediately under their eyes—an advantage never enjoyed by the emmetropic.

Some persons flatter themselves that they enjoy this privilege when at fifty-five the near-point lies at only from 8 to 10 inches, and spectacles have not been found necessary; such persons are proud of their sharp sight, and consider themselves a lucky exception to the laws of decay. Any suggestion as to their being near-sighted is answered in the negative, by a self-complacent smile. On trying them with Snellen's distance-test, placed at 20 feet off, XX, XXX, or even XL, are not recognised, L or LX being the first easily distinguished, and not until they try concave glasses of $\frac{1}{30}$ or $\frac{1}{36}$ can they recognise XXX or XX. Such are consequently myopic. On inquiry, it will generally be found that the parents presented the same peculiarities, when an inference may be drawn that the myopia is hereditary. But the far-point also begins to recede somewhat in the normal eye above the age of fifty; so that it then becomes slightly hypermetropic (distant vision being improved by convex glasses), which at seventy or eighty may = $\frac{1}{24}$ (that is, the patient can see distinctly at a distance with a convex glass of 24 inches focus). In such a case, the hypermetropia, which at first is only acquired (*H. acquisita*), may afterwards become absolute; so that the person is not only unable to accommodate for divergent, but even for parallel rays.

We must be careful not to confound that weakness of sight termed amblyopia with presbyopia, which might easily occur, as an amblyopic person also cannot see small objects distinctly, and convex lenses (by affording him larger retinal images) improve his vision. If the patient cannot with a suitable lens distinguish No. 1 of Jäger at 8 inches distance, but only 4 or 6, or if he is obliged to hold the object nearer to his eye than is warranted by its size, then he is amblyopic. It may be laid down as a practical rule that the nearer we can approximate, by means of convex glasses, the vision and range of accommodation of a presbyopic eye to that of a normal one, the less is the impairment due to amblyopia, and *vice versâ*.

How are we to determine the degree of presbyopia, and correct the deficit of accommodative power?

According to the old method, usually practised in opticians' shops, the patient is tested by the "tryers," "sight-suiters," or "trial case," which consists of a series of carefully worked convex lenses mounted in pairs in tortoiseshell spectacle-fronts, which are clamped together at one end by a pivot that holds them in a box, which also forms a handle to be held by the patient, while each front in turn is placed before his eyes to find which focus enables him to read moderate-sized type at ordinary reading distance, the probable whereabouts of the power required being arrived at by some such guide as the following:—

At **40** years of age convex lenses of **36** inches focal length will *commonly* be required; at **45, 30**; at **50, 24**; at **55, 20**; at **58, 18**; at **60, 16**; at **65, 14**; at **70, 12**; at **75, 10**; at **80, 9**; at **85, 8**; at **90, 7**; at **100, 6**—the three last deep lenses, 8, 7, 6, being rarely required, except for "couched eyes."

After the patient has been once fitted it usually only becomes a matter of increasing the power of his spectacles by the glasses next higher in focal range, on his complaining that those he is then using are not sufficiently strong.

The convex trial case includes the above-named series of 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 24, 30, 36, and also 48 inches foci, the last being sagaciously and judiciously termed "preservers." Such a rule-of-thumb method must, however, soon give place to the more exact system established in recent years by Continental oculists.

According to Donders, the degree of presbyopia may be readily found, thus:—

$$\text{If } p > 8'' = 8 + n, \text{ presbyopia. Pr.} =$$

which simply means, we must deduct the (arbitrary) presbyopic near-point (8 inches) from the absolute presbyopic near-point determined by trial.

If we find a patient's near-point lies at 12 inches, the formula would stand thus–

or supposing it to lie at 16 inches, it is

$$\tfrac{1}{16} - \tfrac{1}{8} = -\tfrac{1}{16}, \text{ Pr.} = \tfrac{1}{16}.$$

This also gives the focus of the convex lens, which would bring the near-point back again to (the arbitrary standard for the near-point) 8 inches.

In the first case, the convex required would be 24 inches; in the second case, 16 inches.

In each case the *difference* between the two fractions expresses the deficit of accommodation the patient labours under. In the former case he would find himself, for distinct vision at 8 inches, *minus* such an amount of accommodation as is equivalent to a 24-inch convex lens, in the latter case to a 16-inch convex lens; consequently, if to the first we artificially supplied a 24-inch convex, and to the second a 16-inch convex, in each case we should correct his presbyopia; and provided that the patient exerts *all* his natural accommodation ($\frac{1}{24}$ and $\frac{1}{16}$ respectively), he would be able to read, etc., at 8 inches. Few persons, however, could sustain such a strain on the ciliary muscles for any length of time without fatigue (asthenopia); but as few persons wish to work for any length of time at so close a distance as 8 inches, a more convenient distance, such as 10, 11, or 12 inches, will answer without overtaxing the natural power of accommodation. The result of theory must, however, always be checked by trial, for it will often be found that strain may be avoided by supplying a weaker lens than the above formula indicates.

The object to be attained in supplying a presbyopic person usually with spectacles should be to reinforce his defective accommodation by convex lenses neither so strong as to supersede his own remaining natural accommodation, nor so weak as to tax it further than it admits of.

For such corrective trials a set of lenses of known focal length, in pairs, is required, together with a spectacle-frame, in which such lenses can be readily fitted and changed. Jäger's frame is the best, as the rings for supporting the glasses are movable, to admit of their distance being regulated, so that the patient can look through the centre of both glasses; and, further, it allows of the centre of the pupils being noted. The set employed on the Continent comprises 28 pairs of bi-convex lenses of 2, 2¼, 2½, 3, 3½, 4, 4½, 5, 5½, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 22, 24, 28, 36, 40, 48, 60, 72, and 100 inches positive focal length, and 28 pair of bi-concave lenses of corresponding negative focal length, together with a set of glass prisms with refracting angles of 3°, 4°, 5°, 6°, 7°, 8°, 9°, 10°, 12°, 14°, 16°, 18°. These usually correspond to the Prussian inch, which differs but little from the English inch, but is less than the Parisian inch. In practice a reduction will rarely be necessary; but it should be remembered that, as a large number of lenses supplied to opticians are of French manufacture, while the English scale is usually employed for measuring focal length, etc., the English inch is only equal to about 0·94 of the Parisian inch. It is evident care must be taken that the lenses used in the optician's trial box also correspond to the French scale, and that his optometer is graduated to the same measure, unless he uses lenses worked to the English scale, when of course the English system must be adopted for "tryers" and optometer. As it is well known that at first, while the amount of presbyopic disturbance is but slight, glasses of $\frac{1}{80}$ are usually sufficient, and also that in proportion as the time of life advances, and the range of accommodation steadily diminishes, stronger and stronger glasses are required, it was not unnatural that opticians and oculists should arrange glasses according to the time of life at which, on an average, they became necessary; but as eyes differ too much to make age alone the criterion in the choice of spectacles, with some amount of justice this old custom has been ridiculed, but as far as emmetropic eyes are concerned, the diminution of the range of accommodation being as a rule regular, the time of life may in general be taken as a guide, if the many circumstances which modify the indications furnished by the time of life be not overlooked.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—V.

To inscribe four equal circles in a circle, each touching two the containing circle (Fig. 48).

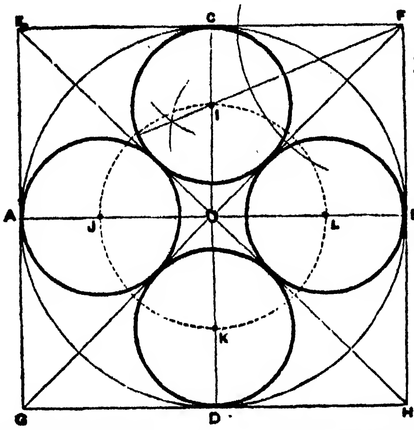


Fig. 48.

Draw the diameters A B and C D at right angles to each other.

From A, B, C, D, with radius of the circle, describe arcs cutting each other in E, F, G, H.

Join these points, and a square will be described about the circle.

Draw the diagonals E H and G F.

Bisect the angle C F O, and produce the bisecting line until it cuts C D in I.

From O, with radius O I, describe a circle cutting the lines A B and C D in J, K, and L.

From these centres, with radius I C, describe the four required circles.

To inscribe seven equal circles in a circle (Fig. 49).

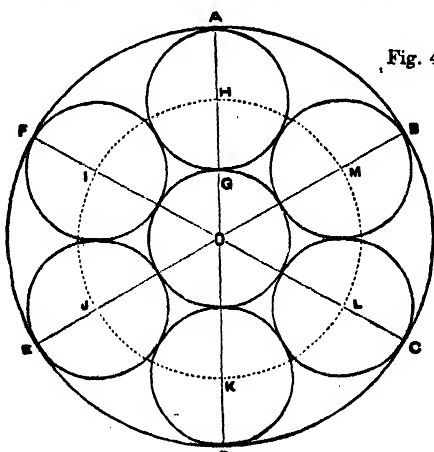


Fig. 49.

Around the circumference of the circle set off the radius, thus dividing it into six equal parts in the points A, B, C, D, E, F, and draw the radii.

Divide one of the radii, as O A, into three equal parts—viz., O G, G H, H A.

From O, with radius O G, describe the central circle.

From O, with radius O H, describe a circle which, cutting the radii, will give the points I, J, K, L, M.

From these points, with radius O G, describe the six circles, each of which will touch the central circle, two others, and the containing circle.

Similarly, a circle O G being given, to draw six equal circles to touch it and each other, divide the circumference of the given circle into six equal parts. Draw radii and produce them. From G set off G H, equal to G O: From O, with radius O H, describe a circle which, cutting the produced radii, will give, with H, the centres I, J, K, L, M of the six circles.

Within a circle to inscribe any number of equal circles, each touching two others and the containing circle (Fig. 50).

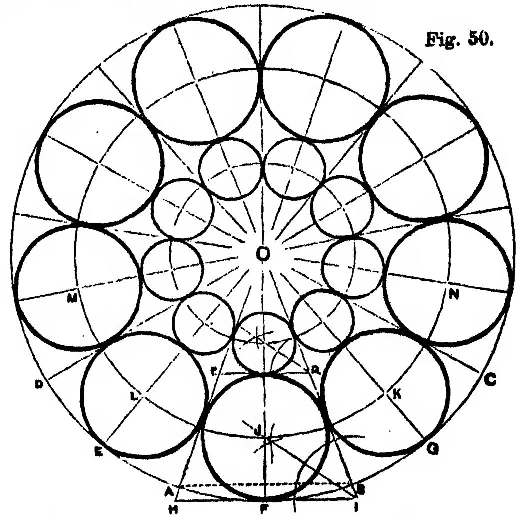


Fig. 50.

Divide the circle into equal sectors, corresponding to the required number of circles—viz., D A, A B, B C, etc., and bisect the sectors by the lines E, F, G, etc.

Produce any two of the radii, as A and B, and draw the tangent H I parallel to A B.

Bisect one of the angles at the base of the isosceles triangle thus formed, and produce the bisecting line until it cuts O F in J.

From O, with radius O J, describe a circle cutting each of the lines which bisect the sectors in L, M, N, K, etc.

From these points, with radius J F, describe the required circles.

By drawing P Q parallel to A B, and bisecting the angle at the base of the triangle, the centre for another circle may be found; and by continuing the process as before, another series of circles may be drawn.

Application of the division of a circle in drawing a rack and trundle (Fig. 51).

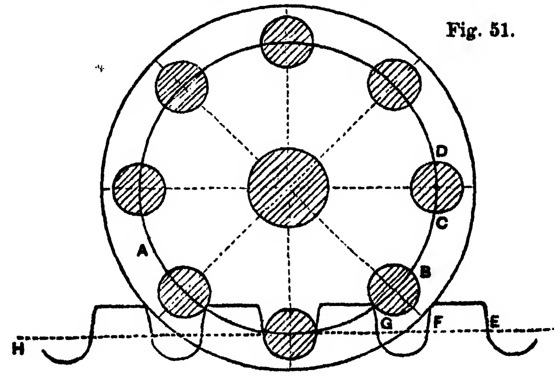


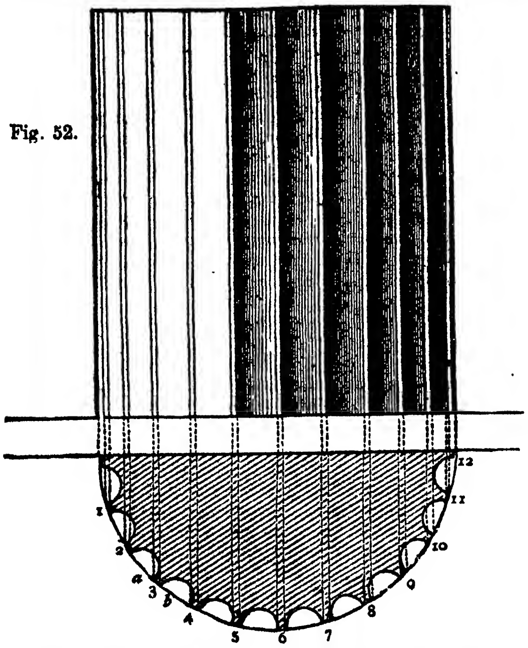
Fig. 51.

The circle A, on which the centres of the circles representing sections of the bars (or teeth of the trundle) are placed, is called the *pitch circle;* and the line on which are the points of contact between the teeth of the rack and those of the wheel, is called the *pitch line.*

The pitch circle must be divided into parts equal to the given number of teeth, and spaces, B C, C D, etc., must be set off on the pitch circle, and similar lengths, E F (= B C), F G (= C D), etc., must be set off on the pitch line H I. The rest of the construction will be readily understood on reference to the figure.

Numerous studies in this branch of the subject will be given in the series of lessons on "Technical Drawing."

Fig. 52.



The above (Fig. 52) is an example of the division of circles in drawing the plan and elevation of a column, and is introduced here in order to impress on students the necessity of acquiring the utmost accuracy in division of spaces.

The circle forming the boundary of the plan is to be divided into a number of parts, corresponding to the required number of flutes—viz., 1, 2, 3, etc.; half the width of the fillets is then to be set off on each side of these divisions, as *a*, *b*, etc., and semicircles drawn from the centres of the remaining spaces.

The elevation of the column is projected by drawing perpendiculars from the various points in the plan.

For full details in the construction of elevations, plans, etc., see lessons in "Projection."

To divide a circle into any number of equal parts, having the same area (Fig. 53).

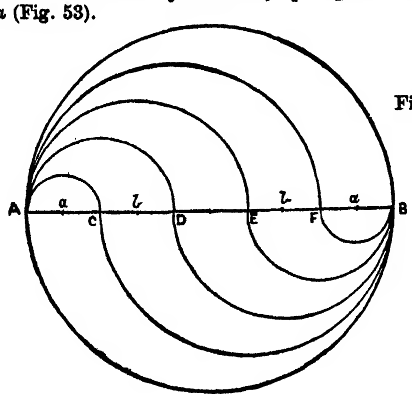


Fig. 53.

Divide the diameter A B into the required number of equal parts, A C, C D, D E, E F, F B.

From points *a*, *a*, midway between A C and F B, describe semicircles, F B and A C.

From point E, describe the semicircle C B.

From D, describe the semicircle F A.

From *b* and *b*, midway between C D and E F, draw the semicircles E A and D B.

From C and F, draw the semicircles D A and E B, which will complete the figure.

To divide a given circle into a given number of concentric rings and central circle having the same area (Fig. 54).

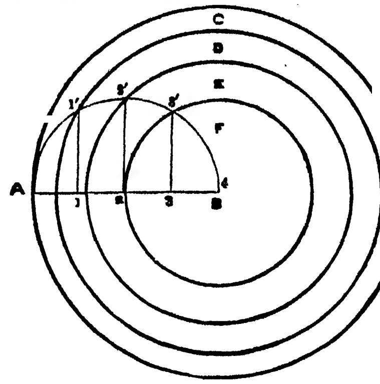


Fig. 54.

Draw a radius A B, and on it describe a semicircle.

Divide the radius A B into the number of equal parts corresponding with the number of rings, etc., required.

From the points of division, 1, 2, 3, raise perpendiculars cutting the semicircle in 1′, 2′, 3′.

Then from the point B as centre, with the radii B 1′, B 2′, B 3′, draw circles passing through the points 1′, 2′, 3′.

The concentric circles passing through these points divide the area of a given circle into three concentric rings, C, D, E, and an inner circle, F, all having an equal area.

The following figure is given as a study of geometrical drawing, showing an ellipse in which the curve is to be drawn by hand. Further studies, also to be drawn by hand, of a semi-elliptical arch, and an elliptical figure formed by arcs of circles, will be given in the next lesson.

To draw an ellipse, the diameters A B *and* C D *being given* (Fig. 55).

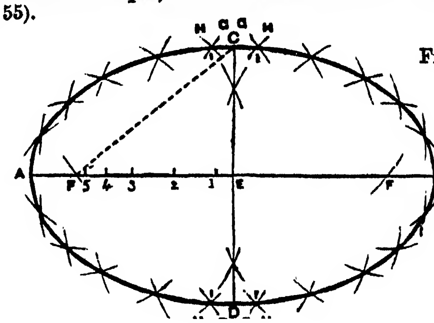


Fig. 55.

Place the diameters A B and C D at right angles to each other, intersecting in E.

Find the foci F and F from C with radius equal to E A.

Between E and F, mark off any number of points, as 1, 2, 3, 4, 5. (It is advisable that these points should be nearer together as they approach F.)

From F, F, with radius 1 B, describe the arcs G, G, G, G.

From F, F, with radius 1 A, describe the arcs H, H, H, H.

The arcs H, H, H, H will intersect the arcs G, G, G, G in I, I, I, I, and these will be four points in the curve.

Proceed to strike arcs from F F, first with 2 B, and then with 2 A; and these intersecting will give four more points.

When arcs have been struck with the lengths from all the points to A and B, the curve of the ellipse must be traced by hand through the intersections.

CHEMISTRY APPLIED TO THE ARTS.—VI.

BY GEORGE GLADSTONE, F.C.S.

HIDES, in common with other animal substances, are liable to putrefaction; and this action cannot readily be stopped, except by a process of drying, which renders the skin hard and

or by that of tanning, in which the softness and pliancy, which are attributes of so much importance, can be retained. Hides and skins—the former term being applied to those of the heavier and larger animals, such as the rhinoceros, buffalo, ox, etc., and the latter to the smaller and lighter, such as the calf, sheep, goat, etc.—are in tanning converted into leather; an operation due to the affinity of tannic acid for the gelatine and albumen as well as the animal membrane contained in the raw article, which leads to the formation of a new compound that is not decomposed by the action of the atmosphere.

The skin of all animals consists of two distinct parts—the epidermis, or scarf-skin, which forms a very thin layer on the exterior surface, and the cutis, or true skin, which lies below. It is with the latter that the tanner has to do. This is a fibrous substance largely composed of gelatine, whereas the other is of a horny character, and is not acted upon by the tannin. The affinity of the true skin for tannic acid may be easily tested, by making an aqueous solution of the latter, and then inserting in it a piece of skin of an ascertained weight, which will take it all up; and the quantity of acid which had been dissolved in the water may then be calculated, by finding the increase in weight which the skin has attained during the operation.

The raw articles are received into the tan-yard in very various conditions. The ox-hides and sheep-skins from the shambles are just in the state in which they came off the slaughtered animals; those received from abroad have, however, undergone some process to keep them from decomposition in the meantime; they are generally either dried, in which case they have become almost rigid, or they are pickled in salt, in which case they retain much of their moistness and pliancy. The East India and Cape supplies are usually dry, and have the hair remaining upon them; the wet, salted hides mostly come from South America.

Before describing the course of treatment to which they are subjected, something must be said of the various substances generally used as sources of tannin. The most familiar of these is oak bark, having until recently been much more exclusively used than now. It still continues to be the only important article containing tannic acid which is obtained in any quantity in this country, though the bark and leaves of most trees contain more or less of this principle. The bark of young trees contains the largest per-centage, and the quantity is greater in spring than at other seasons; but in this country neither of these considerations has much weight, the bark being of secondary importance to the timber, which improves with age, and is best when felled in the summer or autumn. These circumstances serve to account for the great variations in the quality of different parcels of bark, and show the importance of determining by chemical means the quantity of tannin they contain, which cannot be even approximately arrived at by the most experienced judges from the mere appearance of the samples. Birch and willow bark are sometimes used in this country, but the former much more generally in Russia; the agreeable and very permanent odour that distinguishes Russia leather being due to a peculiar oil contained in the bark of the birch.

The warmer climates supply a number of vegetable productions rich in tannin, that are constantly attracting increased attention, and are destined to enter into still more general use, as the home supply of oak bark would not keep pace with the increase of the demand, were the tanner dependent upon it alone. From the shores of the Mediterranean two very important articles are received—sumach and valonia. The former consists of the leaves of the tree so called, which are dried and ground up; the latter is the cup of a particular species of oak that grows extensively in Greece and Turkey, and which is remarkable for its very large acorns.

From the tropics are obtained dividivi, myrobalans, and catechu, which are all rich in tannin. The first of these is the fruit-pod of a tree which grows in tropical South America; the second is the dried fruit of one that is common in India; and the last named (of which there are several varieties, known under the names of terra Japonica, cutch, and gambier), consists of the inspissated juice of certain trees which grow principally in the East Indies. These last are extremely rich in the important elements, being weight for weight about five times as effective in tanning as oak bark.

Of late years the acacia trees, which abound in great variety in Australia, have been found to yield barks which are valuable in tanning, and considerable quantities of leather are now made with the aid of this material.

The value of these different articles to the tanner is not, however, to be measured exactly by the proportion of tannin which they contain. The trade always looks for what is called "bloom" upon the leather, and those substances which produce this effect best are consequently specially appreciated. The want of this quality in the different kinds of catechu detracts from the value which their richness in the tanning properties would otherwise assure to them; while oak bark, valonia, and dividivi are distinguished for the beautiful bloom which they impart. It is also worthy of note that some substances, which are themselves rich in tannic acid, are of no actual value for the manufacture of leather; for though they will produce the chemical action necessary for this purpose, it is found in practice that the leather made with them is liable to decomposition, so that it is wanting in its most important characteristic. Oak-galls, and all other excrescences which are not natural vegetable growths, have this defect; and infusions of them are also very liable to another disadvantage—viz., a readiness to ferment, which results in the conversion of the tannic into gallic acid, the effect of which will be described presently.

The usual processes for converting hides or skins into leather must now be described. If green hides (*i.e.*, those fresh from the slaughterhouse) are to be operated upon, the first thing to be done is to cleanse them, by taking off all the particles of flesh, etc., which may be adhering to them; and then, if they are not to be used at once, they must be pickled in salt to keep them sweet. Foreign hides, which have necessarily been either dried or salted, need a great deal of soaking in water to render them soft and porous; so that a large supply of water is an essential requisite in a tan-yard; and the water should be soft, as the earthy ingredients in hard waters are apt to form insoluble compounds with the fatty matters in the skin, and so prevent the action of the tan.

The next step is to take off the epidermis, and the hair with it. This is commonly done by liming, for which purpose the skins are steeped in vats containing a solution of quicklime in water, from three days to three weeks, according to the nature of the article operated upon, the heaviest hides requiring the longest time. During this process the skins are handled, or turned over periodically, in order to keep the liquor stirred, and so prevent any unevenness of action upon them. The hides are then scraped with a long two-handled knife upon a beam; the beam, as it is called, being a sloping bench with a curved surface, over which the hide is stretched during this operation. The sharp edge of the knife removes the epidermis and the hair at the same time. If the hide is then found to be uneven in thickness, it is turned over, and the inner side is subjected to a scraping and rubbing down until all inequalities are removed.

The preparatory liming has unavoidably caused some of those insoluble compounds which have been already referred to as the result of using hard water; and these must be got rid of before commencing the actual tanning process. For this purpose a "bate," or solution of dogs' dung, is used, in which the hides are steeped for a week or ten days. The "bate" contains an ammoniacal chloride, the chlorine of which combines with the lime, forming a soluble compound that can be easily removed by washing.

There are other modes of preparing for taking off the hair which have their advantages, especially in rendering the bating unnecessary. It may be done by producing a fermentation, for which purpose some milk, or a mixture of meal and water, is very effective. Another mode is technically called "sweating;" it is produced by piling the hides one over the other in a pit, when a considerable heat will be generated, and putrefaction will commence. This will be evidenced by the presence of an ammoniacal odour which will be evolved; and care must then be taken to check the process immediately the hair has become loose, as a continuance of the action would prove deleterious to the quality of the hides. Exposing them to the action of steam in a steam-chest will produce the same loosening effect upon the epidermis, and it is not attended with the risk of injury, which is one of the objections against the sweating process.

The hair having been removed, and the bating (if necessary)

having been accomplished, the next step is to prepare the hide to receive the tan as readily as possible. This is called "raising," the result being the distension of the cellular tissue of the skin, which facilitates the subsequent action of the tan. It may be done either by suspending the hides in a very weak aqueous solution of sulphuric acid, or of spent sour tan—the latter being considered the better, though the slower process.

We now come to the most important part of the whole operation—the tanning, properly so called. This used to occupy a very long time, in some instances as much as two years; but great attention has been paid to the shortening of its duration, and some plans have been devised by which it is possible to accomplish it in a fortnight or so. It is, however, found that a complete combination between the tannic acid and the gelatine is always a matter of time, an excess of the tannin being necessary in order to produce the required effect; and if the operation be performed too rapidly, an inferior leather is sure to be the result. The old plan was to put the hides in pits between layers of ground bark, and leave them there for months, until the bark was considered spent, when the process would be repeated with fresh material, and so on until the hides were sufficiently tanned. It was afterwards found to be more expeditious to introduce tepid water into the pits for the purpose of drawing out the tannin from the bark. Now, an extract of bark, technically called "ooze," is found to be still better. This may be made either with cold or warm water, and the strength of the solution can be regulated as may be desired.

In the tan-yard a series of pits are arranged, with feed-pipes for supplying the ooze, and in these the hides are laid, and then the liquor introduced. The hides must, however, be handled or turned over twice a day at first, being returned into the same or the adjoining pit, the pits being so arranged that the first contains the weakest ooze, and so on up to the strongest or concentrated solution. When they are passed into the stronger ooze, the hides are handled only once a day, and subsequently only once a week or more, up to a month. From this circumstance the pits containing the weakest solutions are called "handlers," and those containing the stronger are termed "layers" and "bloomers;" a concentrated solution being finally used in order to give a bloom to the leather. Heavy hides require usually a period of about eight months to tan them properly with oak bark, and about double their weight of bark; but if the other materials already named are used instead, a proportionately less quantity is required, and the time occupied is also somewhat shorter.

After being finally taken out of the tan-pits the hides have to be carefully dried in a moderately warm chamber, and are usually rolled under heavy brass rollers in order to give them more compactness and a better surface, upon which their marketable value considerably depends.

It has been already stated that the production of leather is due to the action of tannic acid upon the gelatine (of which skin is mainly composed), forming thereof an insoluble compound; but tannic acid has, unfortunately, a great tendency to become oxidised and pass into gallic acid, which will not precipitate gelatine, and cannot, therefore, convert a raw hide into leather. It is therefore necessary that such precautions should be taken as will prevent this chemical change, though in many tan-yards a good deal of gallic acid is produced without its being objected to, as it has the property of swelling the hides, and so rendering them more permeable to the tan liquor; however, the loss in the strength of the latter is not compensated by the action of the gallic acid. An exposure to the air at an elevated temperature is a common cause of the oxidation of the tannic acid; and this action is particularly liable to take place when the vegetable fibre of bark or sumach is left in the solution, the fibre apparently acting the part of a ferment in such cases. Should fermentation have set in, it may readily be stopped by the use of alcohol, carbolic acid, or other similar substances.

It will be seen from the foregoing that the tanning process is a singularly slow one, and though many plans have been suggested for shortening the time required, practical inconveniences have prevented their general application. The discovery of any simple means by which the operation could be materially expedited would confer a most signal benefit upon this large and increasing branch of trade.

PRINCIPLES OF DESIGN.—IX.

By Christopher Dresser, Ph.D., F.L.S., etc.

ART FURNITURE—CHAIRS.

Having considered those principles which are of primary importance to the ornamentist, we may commence our notice of the various manufactures, and consider the particular form of art that should be applied to each, and the special manner in which decorative principles should be considered as applicable to various materials, modes of working, and requirements of individual manufactures.

We shall commence by a consideration of furniture, or cabinet work—first, because articles of furniture occupy a place of greater importance in a room than carpets, wall-papers, or, perhaps, than any other decorative works; and, second, because we shall learn from a consideration of furniture those structural principles which will be of value to us in considering the manner in which all art objects should be formed if they have solid, and not simply superficial, dimensions.

In the present chapter I shall strive to impress the fact that design and ornamentation may be essentially different things, and that in considering the formation of works of furniture these should be regarded as separate and distinct. "Design," says Redgrave, "has reference to the construction of any work both for use and beauty, and therefore includes its ornamentation also. Ornament is merely the decoration of a thing constructed."

The construction of furniture will form the chief theme of this chapter, for unless such works are properly constructed they cannot possibly be useful, and if not useful they would fail to answer the end for which they were contrived.

But before commencing a consideration of the principles involved in the construction of works of furniture, let me summarise what is required in such works if they are to assume the character of art-works.

1. The general form, or mass form, of all constructed works must be carefully considered. The aspect of the "sky-blotch" of an architectural edifice is very important, for as the day wanes the detail fades and parts become blended, till the members compose but one whole, which, when seen from the east, appears as a solid mass drawn in blackness on the glowing sky; this is the sky-blotch. If the edifice *en masse* is pleasing, a great point is gained. Indeed, the general contour should have primary consideration. In like manner, the general form of all works of furniture should first be cared for, and every effort should be made at securing beauty of shape to the general mass.

2. After having cared for the general form, the manner in which the work shall be divided into primary and secondary parts must be considered with reference to the laws of proportion, as stated in my last article.

3. Detail and enrichment may now be considered; but while these cannot be too excellent, they must still be subordinate in obtrusiveness to the general mass, or to the aspect of the work as a whole.

4. The material of which the object is formed must always be worked in the most natural and appropriate manner.

5. The most convenient or appropriate form for an object should always be chosen, for unless this has been done no reasonable hope can be entertained that the work will be satisfactory; for the consideration of utility must in all cases precede the consideration of beauty, as we saw in my last chapter.

Having made these few general remarks, we must pass to consider the structure of works of furniture. The material of which we form our furniture is wood. Wood has a "grain," and the strength of any particular piece largely depends upon the direction of its grain. It may be strong if its grain runs parallel with its length, or weaker if the grain crosses diagonally, or very weak if the grain crosses transversely. However strong the wood, it becomes comparatively much weaker if the grain cross the piece; and however weak the wood, it becomes yet weaker if the grain is transverse. These considerations lead us to see that *the grain of the wood must always be parallel with its length whenever strength is required.*

For our guidance in the formation of works of furniture, I give the following short table of woods arranged as to their strength:—

Iron-wood, from Jamaica—very strong, bearing great lateral pressure.

Box of Illawarra, New South Wales—very strong, but not so strong as iron-wood.

Mountain ash, New South Wales—about two-thirds the strength of iron-wood.

Beech—nearly as strong as mountain ash.

, from New South Wales—not quite so strong as last.

Black dog-wood of Jamaica—three-fourths as strong as the mahogany just named.

Box-wood, Jamaica—not half as strong as the box of New South Wales.

Cedar of Jamaica—half as strong as the mahogany of New South Wales.*

Wood can be got of sufficient length to meet all the requirements of furniture-making, yet we not unfrequently find the arch structurally introduced into such wooden objects while it is an absurdity so to do. The arch was a most ingenious invention, as it affords a means of spanning a large space with small portions of material, as with small stones, and at the same time gives great strength. It is, therefore, of the utmost utility in constructing stone buildings; but in works of furniture, where we have no large space to span, and where wood is of the utmost length required, and is stronger than our requirements demand, the use of the arch becomes structurally foolish and absurd. The folly of this mode of structure becomes more apparent when we notice that a wooden arch is always formed of one or two pieces, and not of very small portions, and when we further consider that, in order to the formation of an arch, the wood must be cut across its grain throughout the greater portion of its length, whereby its strength is materially decreased; while if the arch were formed of small pieces of stone great strength would be secured. Nothing can be more absurd than the practice of imitating in one material a mode of construction which is only legitimate in the case of another material, and of failing to avail ourselves of the particular mode of utilising a material which secures a maximum of desirable results.

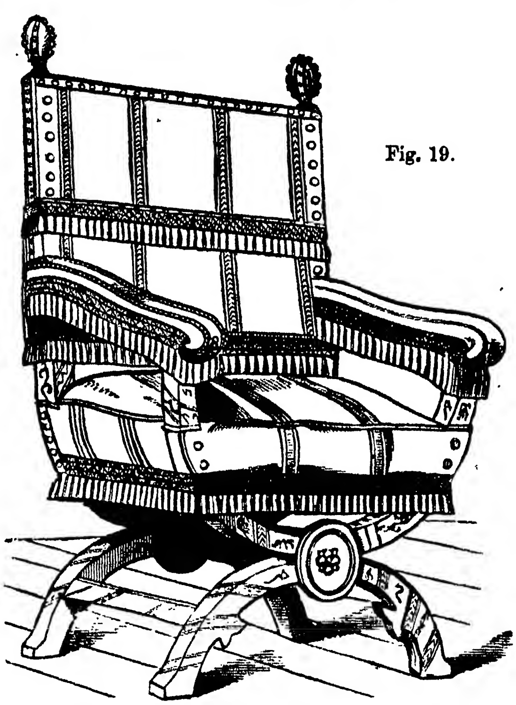


Fig. 19.

While I protest against the arch when structural in furniture, I see no objection to it if used only as a source of beauty, and when so situated as to be free from strain or pressure; but this matter I shall revert to when considering the formation of cabinets, when I shall illustrate my meaning more fully.

One of the objects which we are frequently called upon to construct is a chair. The chair is, throughout Europe and America, considered as a necessity of every house. So largely used are chairs, that one firm at High Wycombe employs 200 hands in making common cane-bottomed chairs alone, and yet we see but few chairs in the market which are well constructed. All chairs having curved frames—whether the curve is in the wood of the back, in the sides of the seat, or in the legs—are constructed on false principles. They are of necessity weak, and being weak are not useful. As they are formed by using wood in a manner which fails to utilise its qualities of strength, these chairs are offensive and absurd. It is true that, through being surrounded by such ill-formed objects from our earliest infancy, the eye often fails to be offended with such works as it would be were they new to it; but this does not show that they are the less offensive and constructively wrong. Besides, whenever wood is cut across the grain, in order that we may get anything approaching the requisite strength, it has to be much thicker and more bulky than would be required were the wood cut with the grain; hence such furniture is unnecessarily heavy and clumsy.

Fig. 19 represents a chair which I have taken the liberty of borrowing from Mr. Eastlake's work on household art.† This chair Mr. Eastlake gives as an illustration of good taste in the construction of furniture; but I give it as an illustration of that which is essentially bad and wrong. The legs are weak, being cross-grained throughout, and the mode of uniting the upper and lower portions of the legs (the two semicircles) by a circular boss is defective in the highest degree. Were I sitting in such a chair, I should be afraid to lean to the right or the left, for fear of the chair giving way. In preference to one of these, give me a Yorkshire rocking-chair, where I know of my insecurity.

A chair is a stool with a back-rest, and a stool is a board or plane elevated from the ground or floor by supports, the degree of elevation being determined by the length of the legs of the person for whom the seat is made, or by the degree of obliquity which the body and legs are desired to take when using the seat. If the seat is to support the body when in an erect sitting posture, about seventeen to eighteen inches will be found a convenient height for the average of persons; but if the legs of the sitter are to take an oblique forward direction, then the seat may be lower.

A stool may consist of a thick piece of wood and of three legs inserted into holes bored in this thick top. If these legs pass through the upper surface of the seat, and are properly wedged in, a useful yet clumsy seat results. In order that the top of the stool be thin and light, it will be necessary that the legs be connected by frames, and it will be well that they be connected twice, once at the top of each leg, so that the seat will rest upon this frame, and once at least two-thirds of the distance from the top. The frame would now stand alone, and although the seat is formed of thin wood it would not crack, as it would be supported all round on the upper frame.

A chair, I have said, is a stool with a back. There is not one chair out of fifty that we find with the back so attached to the seat as to give a maximum of strength. It is usual to make a back-leg and one side of the back of the chair out of one piece of wood—that is, to continue the back-legs up above the seat, and cause them to become the sides of the chair-back. When this is done the wood is almost invariably curved so that the back-legs and the chair-back both incline outwards from the seat. There is no objection whatever to the sides of the back and the legs being formed of the one piece, but there is a great objection to either the supports of the back or the legs being formed of cross-grained wood, as much of their strength is thereby sacrificed. Our illustrations (Figs. 20—25) will give several modes of constructing chairs such as I think legitimate; but I will ask the reader to think for himself upon the construction of a chair, and especially upon the proper means of giving due support to the back, until such time as I converse with him again in my next article.

* For full particulars on this subject see "Catalogue of the Collection illustrating Construction and Building Material," in the South Kensington Museum.

† The title of the work is "Hints on Household Art." It is well worth reading, as much may be learned from it. I think Mr. Eastlake right in many views, yet wrong in others. I cannot help regarding him somewhat as an apostle of ugliness, as he appears to me to despise finish and refinement.

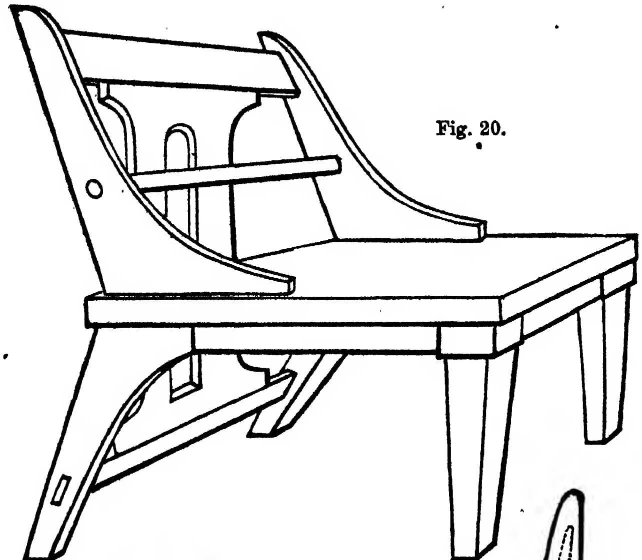


Fig. 20.

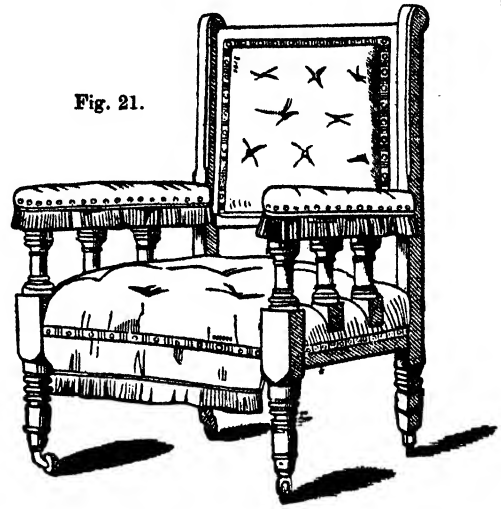


Fig. 21.

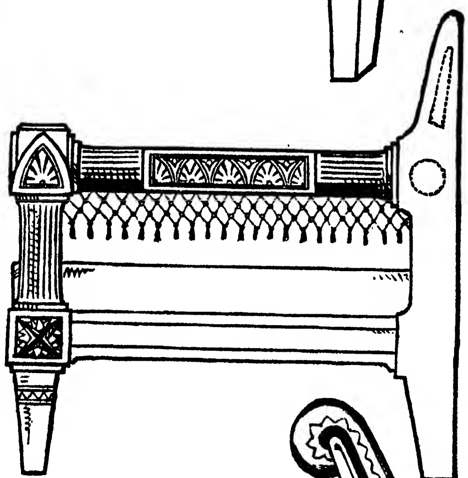


Fig. 22.

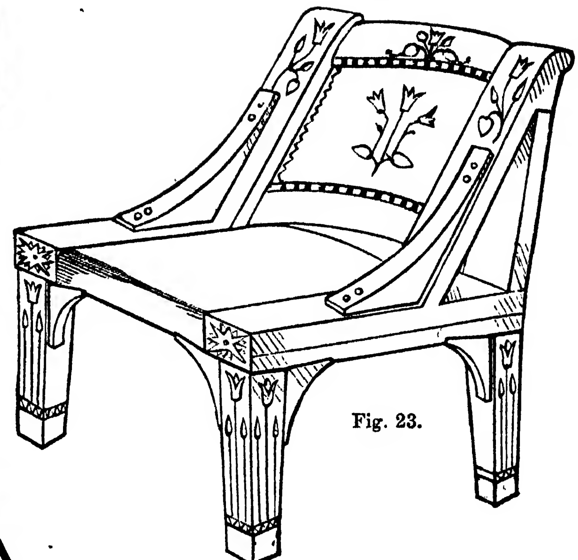


Fig. 23.

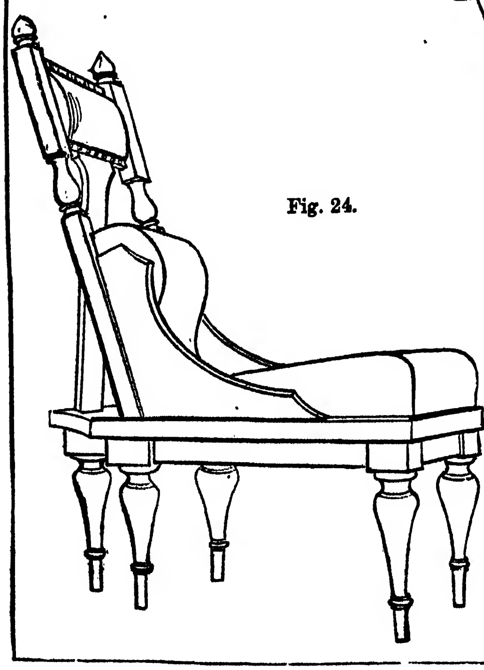


Fig. 24.

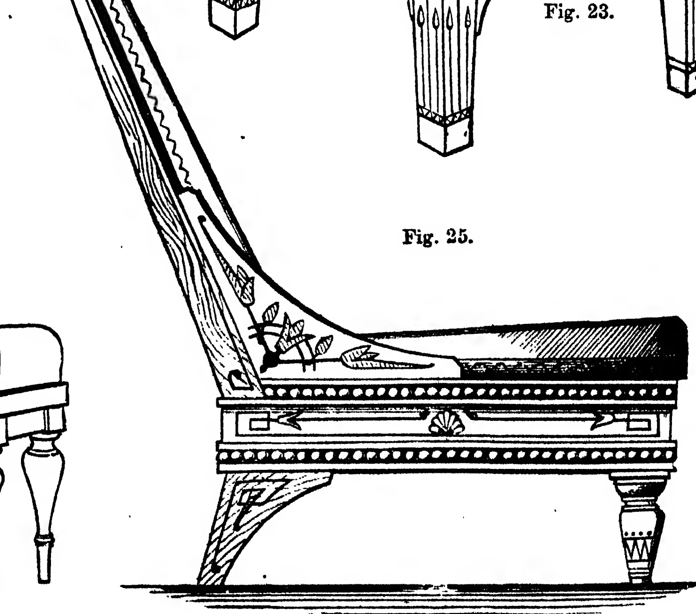


Fig. 25.

CIVIL ENGINEERING.—IV.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

ROADS—CANALS.

The brief allusion we made in a former chapter to the excellent roads constructed by the Romans will indicate to the reader the fact that these, the most useful of all engineering works, are also amongst the earliest. No country can excel in commerce or arts which is destitute of good roads; and in colonising a new territory these are, or should be, the first points to which the engineer directs his attention; for without some mode of conveniently transporting the products of industry from one locality to another, no country can flourish.

It is true that imperial Rome constructed her splendid highways rather with a view to the passage of her armies than to purposes of trade, but they were not the less available for more useful purposes either then or at the present time.

A good road is of use just in the proportion in which it permits of the heaviest loads traversing it in all weathers, with the least expenditure of power. Hence, the two main points to be aimed at in the construction of a road are (1) that it shall be *level*, and (2) that it shall have an *even surface.*

The first of these conditions can be attained only by a survey of the district through which the road is intended to pass. The desirability of a road being *horizontal* is too obvious a point to be enlarged upon; at the same time, unnecessary labour in excavating hills and in raising causeways or embankments over valleys must be avoided. A very slight alteration or temporary deviation from the direction of the proposed route will often be the means of saving an immense amount of labour and expense, without materially increasing the distance, the longest road being frequently the shortest in point of time. Where an extended chain of hills crosses the proposed route, it may become necessary to carry it over the ridge; but the gradient may be considerably diminished by cutting through the summit of the hill, and carrying the excavated soil into the adjoining valleys. Before deciding upon the exact point at which the ridge shall be cut, it will be desirable to examine the nature of the subsoil by frequent borings, as by this means rock may often be avoided.

The duties of the civil engineer may be said to have terminated after he has determined on the course to be taken by the road, and calculated the extent of the cuttings and embankments requisite; but it is absolutely necessary that he shall be practically acquainted with the nature of its construction, to enable him to check the operations of the contractor.

In order that a road shall possess an even surface, it must be composed of materials which will not readily yield to the traffic it will be subjected to. Durability, *in all weathers*, must be aimed at, and this is not always readily attainable. In a dry climate the difficulty is greatly diminished, but in so humid and changeable a climate as our own it is very much increased, whilst the passage of horses and vehicles aggravates the mischief. Hence the question how to construct durable roads in our large towns is one which can scarcely be said even now to be settled, seeing we are unable to pave the streets of even our most crowded cities with square blocks of stone, accurately fitted, as did the Romans.

First, as to *unpaved* roads :—

It must always be remembered that water, when not required, is the greatest enemy which the engineer has to contend with, and with roads it is no exception ; hence, no matter of what material the road be constructed, it should be so formed as readily to throw off the rainfall. A moderately flat curve should be the figure given to the cross-section, the summit being in the centre of the road, and terminating at either side in a sunken channel to receive and carry off the water, which is far more injurious to the road when it is permitted to settle upon the surface. It then gradually soaks into the soil, rendering it soft and spongy, and the first vehicle which passes over it in this state produces an indent in which more water collects, and thus the mischief increases. On this account too much care cannot be bestowed upon the drainage.

The nature of the material employed in constructing a road is of the first importance, but a difficulty frequently arises in procuring the most suitable kind of soil in the district which the road is to traverse, and the haulage of which from a distance may involve an expenditure too great to be incurred.

Telford stands forward prominently as a road engineer. The great road constructed by him in 1816-17, from Carlisle to Glasgow, may be taken as an excellent example of a country road. Its length is 93 miles, it is 34 feet wide between the fences; but the central portion only, for a width of 18 feet, is *metalled*—that is, laid with broken stones; the remaining portion on either side is gravelled. Its cost was £1,000 per mile. The advantage of *metalling* a road lies in this, that the traffic itself assists to consolidate and harden the bottom. The metalling should consist of granite, broken with the hammer, by which the least quantity of the block is pulverised, and the stones retain the sharpness of their edges and angles, thus facilitating their entrance into the soil. The broken stone is spread in a layer over a subsoil, prepared to receive it either by a rake or a pickaxe—the thickness of the layer being regulated according to the nature of the bottom—the furrowing by the pickaxe being requisite to give a hold to the metalling. A light sprinkling of gravel is occasionally thrown over the metalling, which affords an easier footing for quadrupeds, and is in no way detrimental to the formation of the road. The process of metalling by spreading broken stones over the surface is called "macadamising," after the name of the inventor, Macadam, and in this manner may be constructed excellent country roads, suitable, with proper attention, for all ordinary traffic. The *bottom* usually consists of broken stone or brick, rubble, burnt earth, bushes—anything, in fact, which by the action of moisture will not form mud.

The character of the subsoil has much to do with the durability of a road. If it be soft, broken granite, even thickly strewn, will prove a useless because an unendurable surface. This was found to be the case on the road under the Highgate Archway, where, owing to the soft and yielding nature of the subsoil, the only artificial surface which stood the wear and tear of the ordinary through traffic was a composition of gravel and Roman cement, in the proportion of 1 bushel of cement to 8 bushels of washed gravel and sand—the cost being about 2s. per square yard for a thickness of six inches.

Many instances will occur in which the ordinary macadamised road will prove of no value—for example, in building a road across a bog or morass. In this case the plan adopted originally by Metcalf, in the last century, and subsequently by Stephenson, at Chat Moss, has been proved the most efficient. The yielding character of the bog would entirely absorb any soil thrown directly upon it; but by employing a *floating* medium, such as fagots, brushwood, or furze, and extending the width of the base considerably beyond what is required for the purposes of traffic, the soil may be made to rest upon the floating platform, and the road thus formed will efficiently bear up the weight of passing traffic.

A macadamised road is of comparatively little use in a busy town. A *through* traffic is not nearly so injurious to a road as a traffic in which vehicles are often turning—the pivot-wheel acting as a scoop, and producing an abrasion of the surface.

The character of the surface of a road has, as may be supposed, much to do with the amount of friction existing in wheeled traffic. On a gravelled road the friction is 4·5; on an old flint road it is 2·0; a well-made pavement being reckoned as 1·0—facts which at once settle the question of the desirability of maintaining a good surface on a road.

It is an interesting fact, in connection with our subject, that the injury done to an ordinary macadamised road by four horses is three times as great as that done by four *coach*-wheels, but this proportion is considerably increased when the wheels are broad as in wagons. The fact that horses are so injurious to the surface of roads led to the effort, made many years since by Mr. Gurney, to introduce steam-power upon common roads in lieu of horses.

No ordinary macadamised road will withstand the traffic of the streets of large towns without the most continuous attention, and a consequently large outlay. The more usual mode of meeting the difficulty is by a regular paving of stone, of which there are two kinds—the *rubble* and the *ashlar*. A rubble is in reality an imperfectly constructed ashlar pavement. The ashlar causeway consists of hammer-dressed granite stones, from five to seven inches thick, eight to twelve inches long, and twelve inches deep. These stones are laid in regular order upon a foundation consisting of cement, sand, and gravel, which is allowed to set firm, the surface of this bottom being

adjusted by suitable tools to the curve which the cross-section of the finished road is intended to assume. After the surface-stones are arranged upon this bed, they are "set" by copious discharge of thinly-mixed mortar being thrown over them, which settles down into the interstices between the stones and fixes them. The cost of a well-constructed ashlar road varies from 7s. to 10s. per superficial yard. As compared with a macadamised road this is, of course, a high figure; but the difference is only in the first cost, and disappears when the item of maintenance is considered.

In some instances a still more expensive kind of road is constructed to meet special cases, as, for instance, the exceptionally heavy traffic between the Docks and the City of London, or over London Bridge, in which continuous lines of large granite blocks are laid end to end, with flush joints, thus forming a level stone tramway in the wheel-tracks. The blocks vary from 2½ feet to 10 feet long, are 18 inches wide, and 12 inches deep. Such a tramway so far reduces friction as to enable a single horse to draw a load exceeding ten tons at a rate of nearly four miles an hour, an advantage so obvious that, after the success of the experiment had been proved, it was proposed to lay a roadway of the same description between London, Liverpool, and Holyhead, upon which steam carriages might run. The idea was, however, rejected, as it was proved that, with all the care which could be bestowed upon such a road, the friction was still vastly in excess of that upon a smooth iron rail.

A rubble pavement is one in which less care is bestowed upon the shaping and dressing of the stones; hence there is less uniformity in their arrangement, and consequently wider interstices between them.

The maintenance of a roadway is an important item of expense. We have stated that a good ashlar road costs much less to keep it in repair than a macadamised road, the maintenance of the latter costing about 2s. 11d. per superficial yard per annum; but as macadamised roads cannot be entirely dispensed with, it is important to ascertain the best and the most economical method of keeping them in repair. The tendency of traffic is to wear down the surface from an erect curve to a level, or even to an inverted arch—the principal traffic being naturally confined to the centre of the road. This change of figure must be prevented, in order to keep up the lateral drainage; the application of broken stone to all low parts must, therefore, never be neglected. The accumulation of mud must also be carefully avoided. A scraper is usually employed for the latter object, but this implement is, without a doubt, the greatest enemy an ordinary road possesses. Even with the use of Bourne's Multi-dental Scraper it is impossible to prevent the teeth from catching the projecting points of stone, the result of which is that the stone is dragged out of its bed, and a hole is formed. Nor does the mischief end there, for the surrounding stones, which were previously firmly wedged, become loose, and the solidity of the surface is impaired. The broom is the only thing that should be employed to remove loose mud from the surface, and this, if frequently applied before any large accumulation of soil has arisen, will always prove sufficient for the purpose; for, besides doing its work with less injury to the road, it does it better than the scraper, entering more searchingly into the inequalities of the surface.

It must be admitted that an ashlar road, however excellent, is productive of great noise, and an uneasy vibration to the occupants of vehicles passing over it. For this reason, *wooden* blocks have, in several instances, been employed instead of stone; and if this description of pavement could be made as durable, it has manifest advantages over the granite-paved surface. It is almost noiseless—too much so, indeed, for the safety of pedestrians—and the absence of jolting from stone to stone, combined with the yielding character of the surface, is productive of much less injury to the hoofs of the animals and to the springs of the carriages. An attempt has been made to render the surface of the wood more durable by studding it thickly with large-headed nails, but this course has not been successful. Knapp's pavement consists of hollow iron blocks, divided into small compartments, filled with concrete to a level with the surface. Four of these blocks make one square yard. Asphalte has been recently employed in some of the busiest of the London thoroughfares. It forms an excellent surface and an agreeable road.

ı.—The advantages arising from a system of communication which, whilst extending over the interior of a country, is at the same time connected more or less directly with the great highway of nations, the sea, are obvious. But there are other and equally apparent advantages in connection with water transit, advantages which are, however, particularly applicable to *heavy* goods. For instance, the tractive power of a wagon-horse upon a good road may be reckoned at 140 kilogrammes; whilst a *single man* is capable of drawing a load 350 times as great when floating upon water. Friction, in fact, is reduced almost to *nil* when the load is floating, providing the speed is inconsiderable; indeed, the limit of weight to which a man is thus capable of imparting motion is not easily ascertained, but it appears to be bounded only by the *vis inertiæ* of the mass. The advantages, therefore, of canals as means of transport are evident, and vast sums of money have been expended upon their construction in this and other countries. There are, however, serious difficulties in the formation of a canal, requiring considerable talent and forethought on the part of the engineer to overcome.

The first point for consideration is whence to obtain the necessary water-supply. If the course of the canal were one continuous level throughout, communicating at either extremity with some large reservoir retaining a uniform level, there would be no further supply required than what was demanded by evaporation, or absorption by the soil; but if the surface to be traversed is irregular, the introduction of *locks* becomes necessary, and every barge which passes through a lock creates a demand upon the water supplied from the higher ground. The expense of employing pumps to return the water back to the higher level could not for a moment be entertained, except as an expedient during a limited period in dry weather; it is imperative, therefore, that an adequate supply of water should exist to provide for the loss arising from the emptying of the locks; and the highest level of the canal should be so arranged as that it should receive at all times an equable and adequate supply of water from that source.

Next in importance to the water-supply is the consideration of the course to be traversed by the canal. The commercial advantages arising from the contiguity of the canal to large towns must enter largely into the calculations of the engineer in his determination of this point; but above all he must be guided by a consideration of the nature of the surface and subsoil. If the subsoil be porous, consisting of sand or gravel, an undue loss of water will arise from absorption, to prevent which a large outlay must be incurred in puddling the channel with clay; for this reason an absorbent soil should be avoided if possible. A matter of equal importance is the character of the surface; every effort must be made by the engineer to prevent unnecessary excavation, and at the same time to limit as far as possible the number of *locks*, those expensive and inconvenient but indispensable adjuncts to a canal, a further consideration of which we shall reserve for our next chapter.

The engineer is much more restricted in his actions in preparing the plans for a canal than he is in laying out a road, or even a railway, because any deviation from an absolute level is inadmissible without the introduction of a lock. It is usual to lay out a canal in sections, the space intervening between lock and lock—and which therefore occupies the same level—being regarded as a *section*. The object of the engineer is, therefore, to make each section as long as possible, and as direct as the nature of the ground will admit. It is, of course, impossible to maintain one uniform level throughout; but by judiciously availing himself of the side of a hill, winding round its side, and selecting a short valley intervening between one hill and another, and spanning it by an aqueduct, and again skirting the side of another hill, and so on, the number of locks may be greatly reduced. An apt illustration of the skill displayed by the engineer in the selection of the ground may be quoted in the case of the Monmouthshire Canal, which traverses very difficult ground, but which, winding round the side of the Blorenge at the height of several hundred feet above the valley of Crickhowell, enters the upper end of the valley in its course towards Brecon upon one continuous level throughout.

In other instances—for example, the Rochdale Canal between Rochdale and Todmorden—the character of the ground necessitates the use of locks at very short intervals, involving a vast outlay in the first instance, and a great impediment to navigation in the second.

TECHNICAL DRAWING.—XX.

DRAWING FOR MACHINISTS AND ENGINEERS.

FREE-HAND DRAWING (*continued*).

FIG. 209 is a sketch of a common padlock, which affords a good subject for the practice of balancing curves.

Having drawn a central perpendicular, and a horizontal line crossing it, set off the widths A B and A C; then, having determined on the distance A D, draw the curve on the left side—viz., B D—and balance it by the curve C D.

Observe that these curves must not form a point at D, but must merge smoothly into each other.

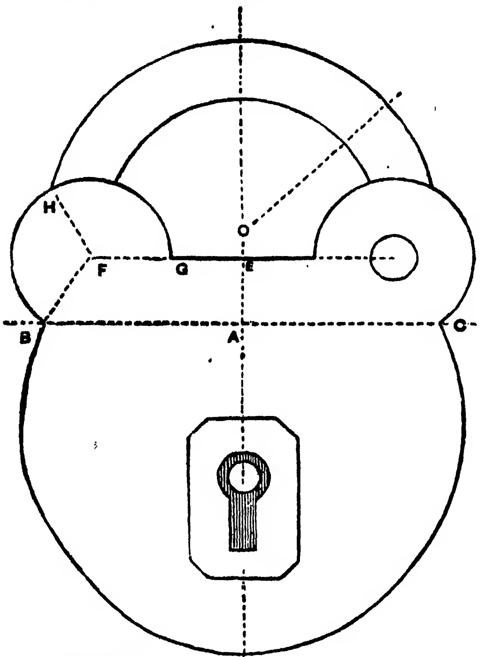


Fig. 209.

Now draw a horizontal line at E, and mark on it, on each side of the central line, a distance corresponding with E G.

Produce this line, and continue the curve beyond B until it meets the straight line in F. The length from G to F and from B to F will then be equal, and thus a circle drawn from F, with the radius F G, would also include B.

Now to draw circles by hand is, to almost all persons, a rather difficult task, but it may be rendered less so by drawing lines from the centre, and marking off on them the radius required, as shown at F H. The curve may then be traced through the points thus obtained. The segments of circles on each side, then, having been drawn, and also the smaller circle representing the rivet, draw the upper portion of the padlock, the centre being at O; and in this, too, the method shown above may be adopted. The keyhole, and plate surrounding it, can, it is hoped, be drawn without further instructions.

Fig. 210 shows the key of this padlock.

Having drawn a central line, and another at right angles to it, draw the rectangle A B C D. Set off E, F, G, H, and thus eight points will be obtained, through which the elliptical head of the key is to be drawn.

It must, however, be understood, that this squaring out of curved forms is merely intended to assist the student in the most elementary stage, and must be discontinued as soon as possible.

The barrel and remaining portions of the key are now to be drawn, and will easily be understood from the copy.

Fig. 211 represents a small iron cramp.

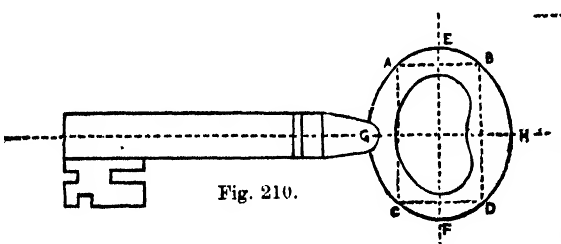


Fig. 210.

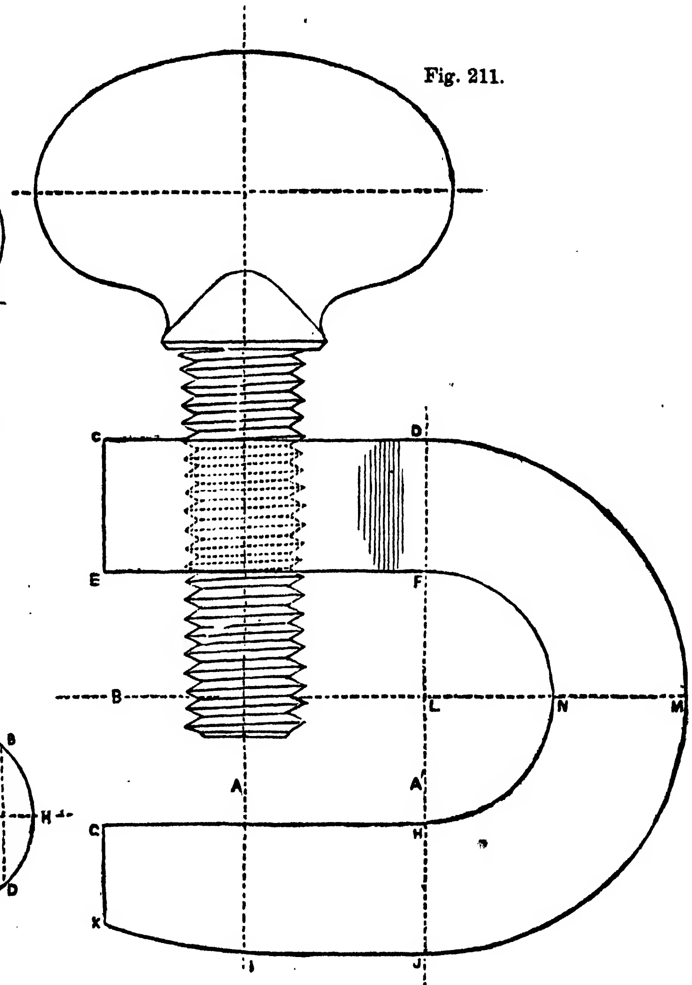


Fig. 211.

Draw the perpendicular A, the horizontal B, and the perpendicular A′, at the required distance from A.

Now draw the horizontals C D, E F, G H, and I J, the extremity of I J being carried upward in a curve to K. Join C E and G K. From L set off L M, equal to L D, and also from L set off L N, equal to L F, and draw the semicircles D M J and F N H, which will complete this portion of the object.

Having drawn the handle of the thumbscrew in the manner shown in the callipers and padlock, draw the perpendiculars for the inner and outer angles of the thread of the screw. The method of drawing a screw in the simplest manner has been shown in Fig. 205. In the present study, however, the lines are to be drawn by *hand* instead of by the aid of the rule.

No further separate studies of free-hand drawing will be given, as it is intended that the student should copy the rough sketches and as many of the mechanical studies by *hand* as he can.

MECHANICAL DRAWING (*continued*).

Fig. 212.—The subject of this lesson is a *rachet-wheel.* This is a contrivance consisting of a wheel, with pins or teeth of a suitable form, which receives an intermittent circular motion from some vibrating piece. In this drawing, E is the rachet-wheel, furnished with saw-like teeth. The driver is a *click* or *paul*, A, jointed at one end to a movable arm, B, which has a vibrating motion on the shaft C as a centre. As B moves towards the left hand it pushes the wheel before it through a certain space, and on its return the click, A, slides over the points of the teeth, and is ready again to push the wheel through the same space as before, being pressed against the teeth either by a spring or its own weight. A *detent*, D, prevents the wheel from receding, whilst the click is moving over the teeth.

The first step in drawing this figure is to trace the two circles between which the teeth are to be contained.

These should be very lightly drawn, as no portion of either circle is to be used in the drawing; but they are required to ensure uniformity in the teeth.

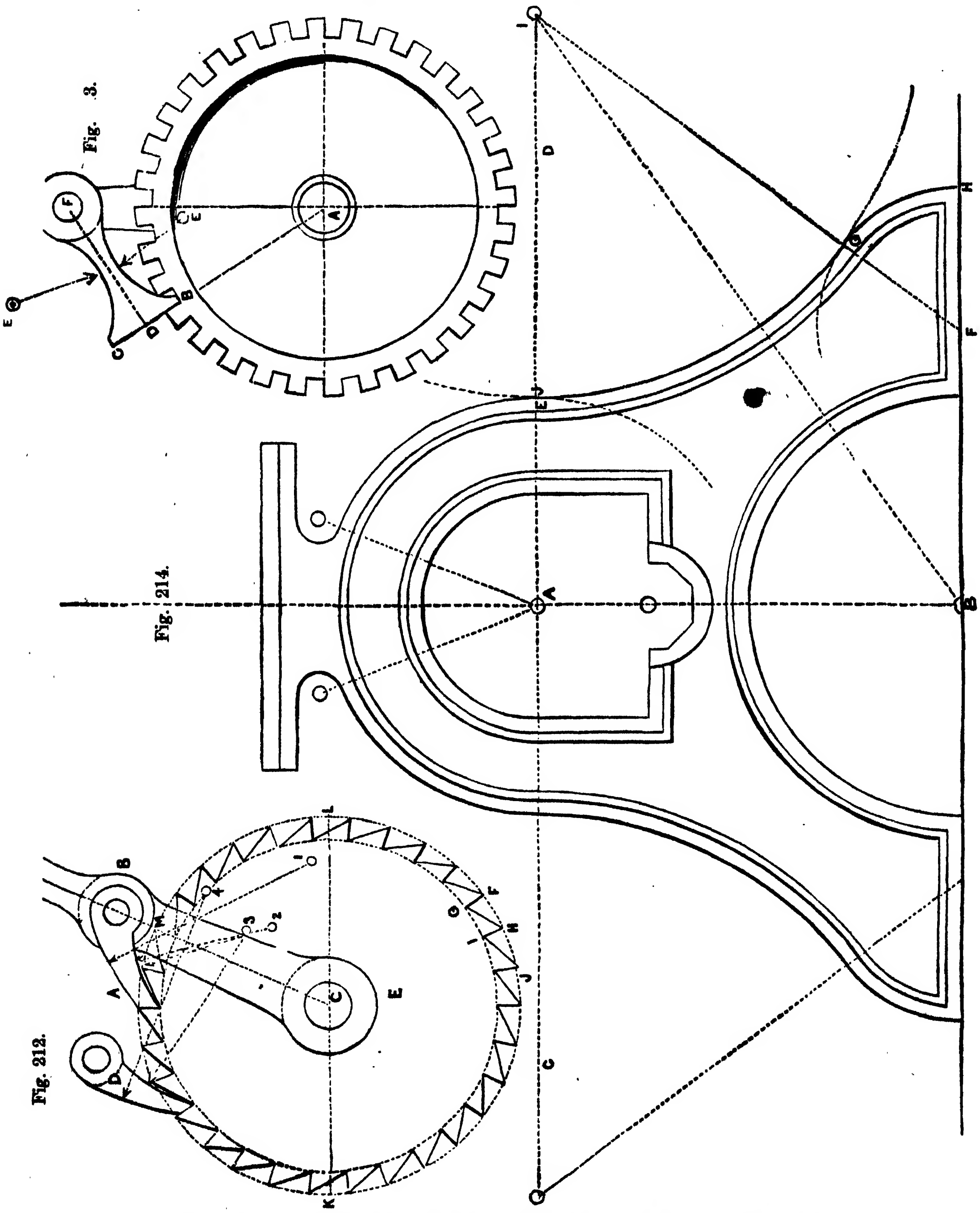


Fig. 3.

Fig. 214.

Fig. 212.

Now, divide the outer circle into the number of parts required for the teeth. There is no special reason why the outer circle should be divided rather than the inner; it is merely that errors in division are more readily seen in large than in small circles. Where numerous divisions are required, some draughtsmen draw a circle outside the one to be divided and of a much

larger radius; on this they set off the required divisions, and from them draw lines to the centre; these lines passing through the original circle, divide it without fraying the paper or otherwise injuring the clearness of the work.

The outer circle then being divided, draw lines to the centre; it will not be necessary to draw these radii the whole of the distance, but only between the two circles, to form the faces of the teeth, as shown at F G, H I, etc.

Join the outer end of each line to the inner end of the next, as H G, J I, etc. These lines will form the backs of the teeth.

We now proceed to the arm, and for this the centre line must be drawn. Now it is necessary that, in copying a drawing, the exact inclination of such an arm or other part should be accurately given. To accomplish this, draw the diameter K L, measure from L on the circumference of the circle the length of the arc L M, and draw a line from the centre C through M.

Then construct on your drawing an angle similar to L C M, and the line C M will give the inclination required. This method can be applied without reference to size, for it will be remembered that the number of degrees an angle contains is not altered by the length of the lines of which it is formed.

Having then drawn the line C M, set off on it the centre of the click, and complete the arm, setting off the widths on the circles at top and bottom. The straight sides are to be joined to the circles by small arcs, or by curves drawn by hand.

The centres for the click and detent, and those from which their inner and outer curves are struck, are to be found in the same way.

It will be seen that, owing to the form of teeth shown in this figure, the wheel can only be driven in one direction; but in machines for cutting metal it is frequently necessary that it should work either one way or the other. Sir Joseph Whitworth adopts in such cases the construction shown in Fig. 213, called Clement's catch.

Here the rachet-wheel has teeth, the ends of which are bounded by the circle, and the flanks of which are portions of the radii, whilst the click is so formed that it will either work as shown in the example, or may be turned over to act in the opposite direction.

In drawing this figure, describe the circles for the inner and outer ends of the teeth; divide the outer circle into the required number of equal parts, the teeth and spaces being equal; draw the sides of the teeth by lines from the points of division to the centre, and join those lines which are to form teeth on the outer circle, and such as are to form spaces on the inner circle.

The click is now to be drawn. Having fixed the centre, F, draw the line B C, which is radial to the circle.

Bisect B C in D, and the bisecting line D F will be the central line for the click; the centres for the arcs forming the sides are shown at E and E′.

Fig. 214 is a portion of the *frame of a pump*, and is here introduced as a study in joining circles, the whole of the external form being described by portions of three circles touching each other.

Having drawn the base-line and perpendicular, B, mark on it the point A, and through it draw the horizontal C D.

With radius A E, describe a semicircle.

From B set off B F.

From F, with radius F G, describe the arc G H.

From F draw a line through G, cutting the line C D in I.

From I, with radius I J, describe an arc, joining the semicircle to the arc last drawn. The rest of the drawing being obvious, it is hoped that, after this fundamental construction has been correctly done, the remaining portion will be accomplished without further instructions.

COLOUR.—VI.

By Professor A. H. Church, M.A., Royal Academy.

COLOURS WITH WHITE, GREY, AND BLACK—OCULAR MODIFICATIONS OF COLOUR—PERSISTENCE OF COLOUR-IMPRESSIONS—IRRADIATION—SUBJECTIVE COLOURS—CONTACT AND SEPARATION OF COLOURS.

We have seen, in the last lesson, that there are two kinds of contrast—the contrast produced by difference of tone and the contrast produced by difference of colour. We have also seen that these contrasts are produced under several conditions, and that they are modified through the mode in which they are perceived by the eye and impressed upon the mind. No sooner, in fact, are two colours so placed as to be seen at the same time or in quick succession, than they are apparently changed. The change may be one of tone only, of colour only, or of both tone and colour. Nor is it necessary, in such experiments, that two colours should be used: we may employ two tones of the same colour or a single tone of colour with white, grey, or black. We have already studied the apparent changes which the primary and secondary colours mutually cause when placed in contiguity, and so may now proceed to state what modifying influences white, grey, and black respectively produce upon the most important colours (see Figs. IX., X., and XI. in coloured plate).

1. Yellow.—*Yellow* with *white* is rendered darker, less luminous, and less prominent, and acquires a faint greenish hue. The lighter the tone of the yellow, the less pleasing is the combination.

Yellow with *grey* is rendered darker, less luminous, and perhaps a trifle more orange. When the grey is of about the same intensity or tone as the yellow, the combination is not satisfactory; but it becomes so when the grey is rather deep, the yellow then recovering brightness.

Yellow with *black* is rendered lighter or paler, more luminous, and more prominent. The combination affords the most intense contrast next to that of white with black. The blackness of the black acquires a somewhat bluish-violet hue, which has a tendency to enrich it.

2. Orange.—*Orange* with *white* is rendered darker, and perhaps a trifle more reddish. The contrast between orange and white is much greater than that between yellow and white, and the combination is consequently more effective.

Orange with *grey*, when the latter is pale, is darkened and reddened. With deep tones of grey, orange becomes more luminous.

Orange with *black* becomes more luminous and yellower; the contrast is next in intensity to that afforded by yellow with black.

3. Red.—*Red* with *white* becomes more intense and of deeper tone. The combination, as to intensity of contrast, is similar to that of green with white; being less decided than that of blue and violet with white, but more so than that of yellow and orange with white.

Red with *grey*, where the latter is pale, becomes more intense, deeper, and occasionally acquires a slight bluish hue.

Red with *black* becomes more luminous and slightly yellower.

4. Violet.—*Violet* with *white* affords a contrast of very decided character, owing to the great difference of tone between a full violet and white. The violet is rendered deeper in tone in this combination.

Violet with *grey*.—The distinctive colour of the violet makes itself felt in this combination, which is a quiet and agreeable one.

Violet with *black* affords an instance of the harmony of analogy rather than of contrast. The violet is enriched by its proximity with black; but the latter thereby acquires a rusty hue, which takes away from its richness.

5. Blue.—*Blue* with *white* constitutes a pleasing combination. The contrast is very decided where the tone of blue is deep. The effect of white clouds in deepening the tone of the sky is a good example of one of the chief characteristics of this combination.

Blue with *grey*.—Grey enhances the tone and quality of blue, deepening it to a remarkable extent under certain circumstances.

Blue with *black*.—This combination resembles that of violet and black, but is less agreeable, especially where the blue is of a deep tone. Light shades of blue are rendered paler and more luminous by contiguity with black.

6. Green.—*Green* with *white* becomes more intense and of a deeper tone; green is distinctly improved by the presence of white.

Green with *grey* becomes deeper in tone.

Green with *black* is rendered rather lighter in tone, and more brilliant; but the black suffers in purity, and becomes slightly tinged with a ruddy hue—the result of adding to the black, red, the complementary colour of the neighbouring green.

From what has been said in the preceding paragraphs, it will

have been seen that the effect of white upon a colour is to enhance its quality and deepen its tone; for white, presenting the maximum of luminosity itself, naturally lowers the apparent luminosity of coloured surface in contact with it. (We employ the term *luminosity* here in its common acceptation, not in its scientific sense as previously explained in Lesson I.) But the white is capable of enhancing the quality of a colour for a different reason (explained already when speaking of "Simultaneous Contrasts"). In virtue of this principle, the white, in contiguity with a colour, has a tendency to become tinctured with the complementary of that colour; the presence of this trace of the complementary colour enhances the quality of the original colour itself, in obedience to the law of contrast: the same effect is observed, also, with grey and black when placed in contiguity with colours.

This remarkable law of contrast, of which we are now speaking, may, indeed, in its widest terms and most general application, be summed up in the statement that two differing colours or differing tones tend, when placed together, to differ still more. Light tones and colours become lighter, dark tones darker, complementary colours are mutually enhanced in distinctness; and where a colour is present without its complementary, that complementary is, as it were, evolved, owing to extra sensibility of the eye for those colours which are not presented to it when it has been excited and fatigued by those at which it has been gazing. Before studying the more complex combinations of colours and their applications in the arts, it will be expedient to develop a little more fully some of those principles on which the "subjective" or "ocular" modifications of colours depend. To such phenomena we have just now, as well as on former occasions, briefly alluded; but we are now in a position to extend and amplify our previous observations.

The subjective modifications which colours suffer arise from at least three causes.

First of all, we have the persistence of the impression on the retina of the eye.* The discharge of a Leyden jar gives a spark which is sensibly instantaneous, and yet the impression which it makes upon the eye endures a distinct fraction of a second. The spokes of a rapidly-revolving wheel are seen with perfect distinctness and perfectly separate if it be illuminated by an electric spark, although in an ordinary light they may present a shadowy surface, where all the elements of the wheel are blended together. Yet the apparent solidity of this surface may be proved to be unreal by its approximative transparency to objects placed on the further side of it. These objects, if properly lighted, can be readily perceived through the shadowy surface previously described. Similarly with a series of flashes of electric sparks; if these follow one another at intervals less than the period during which the impression of each spark remains upon the retina, the resultant effect will be that of a continuous light. A familiar example of this persistence of impressions upon the retina is to be found in the experiment of rapidly whirling a glowing stick or piece of red-hot charcoal; a continuous circle of light being produced under these circumstances, if the rotation be sufficiently rapid. Now the effect of this peculiarity of the optical arrangements of the human eye is very marked in the case of colours; but it does not take place exactly in the direction in which we might expect it. It would be imagined that if one of the eyes has been looking at a yellow disc or other yellow object it would perceive, when directed upon a blue object, a mixture of yellow and blue, or a colour lying between them. However, under such circumstances the blue object, so far from acquiring a greenish tinge, becomes rather tinctured with a violet hue. This effect is really one of subjective colour, as well as of persistent vision; for the eye having seen a yellow object is partially blinded or paralysed, so far as that component of white is concerned; acquiring, on the other hand, greater sensitiveness to the perception of the complementary of yellow—that is, violet. White surfaces, or even coloured surfaces, which, of course, reflect much white light, will then have their violet or red and blue constituents brought into unusual prominence by the previous perception of yellow, and will be consequently tinctured with violet. As it is difficult to carry out mentally, from this principle, the whole scheme of alterations of colour effected by the peculiar kind of contrast just described, we shall here give a list of the principal colours as modified by the previous perception of others. Before doing so, it may be advisable to give our readers a method of proving for themselves that such modifications really occur.

Close the right eye, and then look steadily with the left at a sheet of *red* paper. When the red paper appears dull, owing to the special sort of fatigue it induces in the eye, look immediately, still with the left eye, upon a sheet of *violet* paper. The violet paper receiving the complementary of red—namely, green—becomes much bluer. To verify this observation it is only necessary, after having closed the left eye, to open the right, and to look with it upon the sheet of violet paper. The violet will be perceived very differently now, and so far from being bluer than in reality, may actually appear modified in the contrary direction—becoming more red, instead of more blue. To be performed with successful and distinct results, such experiments as these require great care and frequent repetition. Moreover, different individuals have very different powers of appreciating colours and of recording their impressions. One eye, also, will often be found to differ from its fellow in many important particulars. Notwithstanding the delicacy and difficulty which may be experienced in determining the special relations of contrast (often called "mixed contrast") now under consideration, they are of considerable importance in the practice of some kinds of decorative art.

We now give our list of the modifications induced by mixed contrasts of colour.

If the eye has first seen	*and then looks at*	*the latter colour will appear*
Yellow,	orange,	reddish-orange.
Yellow,	red,	reddish-violet.
Yellow,	violet,	bluish-violet.
Yellow	blue,	violet-blue.
Yellow,	green,	bluish-green.
Orange,	yellow,	greenish-yellow.
Orange,	red,	reddish-violet.
Orange,	violet,	bluish-violet.
Orange,	blue,	tinged with violet.
Orange,	green,	bluish-green.
Red,	yellow,	greenish-yellow.
Red,	orange,	yellow.
Red,	violet,	indigo-blue.
Red,	blue,	greenish-blue.
Red,	green,	bluish-green.
Violet,	yellow,	slightly greenish.
Violet,	orange,	yellowish-orange.
Violet,	red,	orange-red.
Violet,	blue,	greenish-blue.
Violet,	green,	yellowish-green.
Blue,	yellow,	orange-yellow.
Blue,	orange,	yellower.
Blue,	red,	orange-red.
Blue,	violet,	reddish-violet.
Blue,	green,	yellowish-green.
Green,	yellow,	orange-yellow.
Green,	orange,	reddish-orange.
Green,	red,	tinged with violet.
Green,	violet,	reddish-violet.
Green,	blue,	violet-blue.

It must not be forgotten that the above modifications of colour, arising from mixed contrast, differ not only in intensity, but in persistence. The modification produced by the successive view of violet and yellow is stronger and more persistent than that produced by the successive view of blue and orange; green is but slightly modified, and for a brief space of time only, by the previous view of red, and so on. And the above-described effects of contrast are influenced, to a great degree, by the difference of tone between the colours successively observed. A dark blue viewed after orange may actually appear somewhat greenish, when the normal modification would be precisely in the opposite direction—that is, towards violet; yet this change occurs most conspicuously when the blue is of not too full a tone. Among the most important cases, constantly occurring in common life or artistic practice, of modifications of colours arising from persistence of the impressions made on the retina, we may cite the difficulty experienced by painters, from gazing too long at any bright-coloured object, natural or artificial, of reproducing or

* Illustrations of the remarkable effects produced by persistence of vision, and the imitation of this natural effect by various scientific toys, will be found in the articles entitled "Recreative Science" which appear in THE POPULAR EDUCATOR.

matching its tone and hue. Again, we may allude to the well-known instance of the purchaser of coloured fabrics. If a series of bright yellow fabrics be displayed, and then some pieces of orange or red stuff, this latter is regarded as dull, and to have a crimson or even a violet tinge. Under such circumstances, the retina, fatigued by the sight of yellow, has a tendency to appreciate and perceive violet, its complementary, more distinctly. Thus much of the yellow in the orange stuff is suppressed, and it appears redder than it really is; red similarly acquires a violet tinge. Doubtless much of the weariness experienced by a long examination of the pictures in an exhibition of modern works of art is due to eye-fatigue, and the consequent ocular modifications of colour.

The second subjective or ocular cause of apparent changes in the colours of objects is due to a defect of the organ of vision. The eye suffers from what in optical language is termed "spherical aberration"—a scattered light, of varying degrees of intensity, always surrounding the defined images of luminous and strongly illuminated objects upon the retina. The result of this nebulous border about such images is to increase their apparent size; but it is nearly always imperceptible under the ordinary conditions of moderate illumination. When, however, we look at incandescent or glowing and luminous bodies, the effect is very striking. A piece of charcoal no thicker than one's finger, if lighted at one end and plunged in oxygen, appears actually to swell as the combustion becomes more intense and the light brighter. A spiral of platinum wire heated to whiteness by a galvanic current not only has its diameter, so far as the wire itself is concerned, enormously increased, but the separate turns of the spiral seem to approach and even to coalesce, if not originally too distant. The crescent of the moon appears, for the same reason, to belong to a much larger sphere than the dimmer mass of the satellite which it clasps. Much of the peculiar indefiniteness and mystery which impart considerable beauty to flames of different kinds, to strongly illuminated clouds and surfaces of water, and to the intense reflected lights of metallic ornaments, is due, in part at least, to irradiation, which, moreover, is one of the chief causes by which coloured margins are so frequently observed to surround coloured objects. A rim of greenish light may be observed round a red wafer placed on white paper, owing to the extension of the image of the red wafer beyond its geometrical image on the retina of the eye. Of course the rim is green, owing to the effect of simultaneous contrast. With a pure yellow, such as that of the spectrum, or that made by mixing green and red *lights* together, the rim of irradiate colour would be blue. This effect is roughly shown in Fig. III. of our coloured plate.

The third ocular cause of the modification of colour has been already dwelt upon at some length, and in different places, in the present series of lessons: it is the production of subjective complementary colours. We may just allude to the phenomenon here, in order that this most important and fundamental fact may be thoroughly impressed upon the minds of our readers. Simply stated, the cause of the phenomenon may be traced to the impaired sensibility to light temporarily caused by the action of light upon the optic nerve. Not only is this true of white light, but of light of every colour. Not only does a moderately lighted room appear dark when we first enter it from broad sunshine, but, as we have before stated, the last piece of yellow or red cloth we look at will seem duller than the first, though they have all been cut from the same roll. When light of any particular colour falls upon the eye, it becomes less sensitive to, and less appreciative of, that colour; it is partially blinded to its perception. So, not only will a red wafer placed upon a sheet of white paper be surrounded by a rim of colour through irradiation, but that rim will be green; and if the wafer be moved away, a green spot will occupy its former position. For the eye, by gazing at the red wafer, has had its sensibility to red light temporarily impaired, and so the white light received on that particular spot of the retina previously occupied by the red tinge of the wafer will have its red constituent virtually removed, and will produce the effect of the residual rays—namely, a green image, the complementary of the previous red one. Several other contrivances for producing subjective complementary colours have been devised. One of the most satisfactory of these is to view a surface of white, grey, or coloured paper, moderately illuminated, through an aperture in another sheet of paper of a different colour, and placed at a little distance above or before it. The lower surface, as seen through the aperture, will be tinged with the complementary of the coloured surface above. So, also, the shadow of an object interposed in a beam of coloured light will, if received on a screen slightly illuminated with white light, appear to have assumed the colour complementary to that of the beam; and, for the same reason, a beam of daylight finding its way into a room illuminated with yellowish light from candle-flames, will appear violet. The importance of this fact, as regards the proper treatment of shadows in painting, will have to be insisted on and illustrated farther on in the present course.

We have now studied the mutual effects of many pairs of colours, the effects of white, grey, and black upon single colours, and the effect on a second colour of the previous perception of another. We have then passed to the causes, dependent upon the structure of the human eye, which modify the natural appearance of coloured objects. We may fitly close this lesson with a few remarks on the uses which may be made of some of the facts and laws which have just been stated, confining our attention at present, however, to those effects of the apposition and separation of coloured spaces which are illustrated in our coloured plate.

We have before stated that the yellow is the most forcible, luminous, and prominent of the primary colours. It will appear nearer to the eye than either red or blue. In Fig. IV. (coloured plate) a yellow leaf pattern is represented upon a ground partially red and partially blue. While there is no doubt of the prominence of the yellow, it will probably be allowed that the red ground appears nearer than the blue; and if the blue had been of a purer and fuller tone still, the retiring effect which it possesses would have been still more perceptible. How far the retiring effect of blue is due to association or fancy, to our constant view of the sky and the hazy distance of a landscape, it is difficult to determine. But there can be no doubt that we are obliged, in decorative and pictorial art, to recognise the idea of distance conveyed by blue and bluish hues, and that such colours afford means of attaining effects of mystery, obscurity, hollowness, etc., which other hues do not furnish. Another association with the colour blue is that of coolness, just as red recalls the glowing warmth of a fire, and yellow the bright shining of the sun. Another feature of our diagram (Fig. IV.) is the distinctness of the sensation imparted by the three colours, yellow, red, and blue. If the red approaches the yellow rather more closely than the latter does the blue, it arises from the impossibility of representing by actual pigments these three colours.

Figs. V. and VI. teach another fact relating to coloured spaces in contact. Often when we attempt to mix colours, our mixture is anything but successful. The difficulty of getting a good violet by adding blue and red together is well known. The result may be achieved in a different way. If lines or dots of red and blue be distributed suitably over a surface, the effect of violet will be produced—at all events, when the figure is held at some distance. One mode of accomplishing this result is seen in Fig. VI., where the distinction of the two colours is lost, and a mixed colour effect produced, in obedience to the laws of subjective colours already announced. In Fig. V. the two colours retain their distinctness at ordinary small distances.

When two colours of about the same intensity and tone, as the blue and yellowish or leaf-green in the central stripes of Figs. VII., and VIII., are in contact, there is a want of distinctness and purity about the margins of the contiguous colours, which renders the combination by no means a pleasing or favourite one. Yet a bright leaf-green is often seen in Nature against the deep blue of a summer sky, and no one dreams of quarrelling with this arrangement of colour. There are, however, delicate differences between the natural and artificial appositions of green and blue. The green leaves of trees are full of minute variations of tone, structure, and form, and they are further helped to contrast with the more uniform blue beyond them by the reflected illumination of some of the edges and the shading or darkening of others. The latter modification may be represented to us roughly in Fig. VIII. Here we see the enormous importance of white and of black, even in the narrowest lines and smallest quantities, in separating related colours. Such colours, difficult as they are to harmonise successfully under many ordinary conditions, afford by the aid of black or white combinations of great delicacy and beauty.

ANIMAL COMMERCIAL PRODUCTS.—XIII.

I.—DYES.

Some of the Mollusca furnish dyes and pigments. The *Murex* yields various shades of purple and crimson. The celebrated Tyrian purple was formerly obtained from *Murex trunculus.* The cuttle-fish (*Sepia officinalis*), which clouds the water by ejecting from its ink-bag a deep black fluid, thus effectually concealing itself, supplies the well-known pigment, *sepia*, of a deep brown-black colour; and a calcareous spongy plate, found in the same fish, is used as a substitute for emery or sand-paper, and as a dentifrice.

II.—SHELLS.

The beautiful variety of form and colour in shells has in all ages attracted notice. Among savages shells are used for personal adornment, and made into domestic utensils, such as knives, spoons, drinking-cups, fish-hooks, and even razors. The wampum belts of some of the North American tribes are made of shells. A small species of white glossy shell, called cowry (*Cypræa moneta*, Figs. 1, 2), abundant in the Asiatic and African shores, is used as money in small payments in India and throughout extensive districts in Africa, 100 being equivalent to one penny. The same cowries are converted into a glaze for earthenware and an enamel for clock faces. *Cypræa coccinella* (Fig. 3) is found in the English Channel. The thin inner layers of a large flat bivalve (*Placuna placenta*) found in the Chinese sea, remarkable for their transparency and the absence of the nacreous or pearly layer within, are used by the Chinese for windows instead of glass. In Roman Catholic countries clam shells form receptacles for holy water; while some, perfectly white, are cut up for arm-rings and other ornaments. The *Voluta gravis*, or chank shell of India, fished up by divers in the Gulf of Manaar on the north-west coast of Ceylon, is exported to India, where it is sawn into rings of various sizes, and worn on the arms, legs, fingers, and toes, by the Hindoos. The demand for these shells is caused by the religious rites of the Hindoos, and some choice specimens of them are valued at their weight in gold. The helmet (*Cassis*, Fig. 4) supplies pieces large enough for umbrella handles, and the nacreous or inner layers of this shell, and other species, are exquisitely sculptured by Italian artists in imitation of antique cameos, and employed for rings, brooches, pins, bracelets, and other ornaments.


Fig. 1.

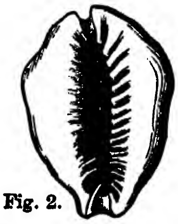


Fig. 2.


Fig. 3.


Fig. 5.

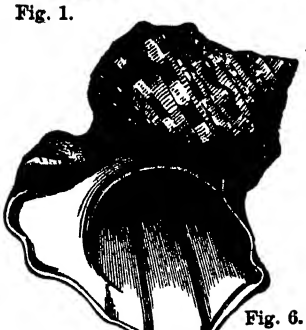


Fig. 6.

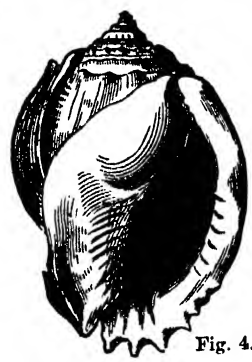


Fig. 4.

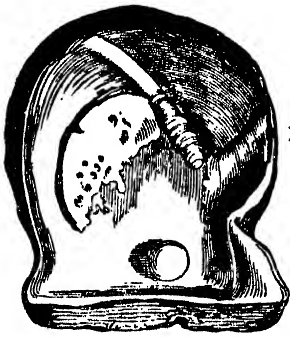


Fig. 8.

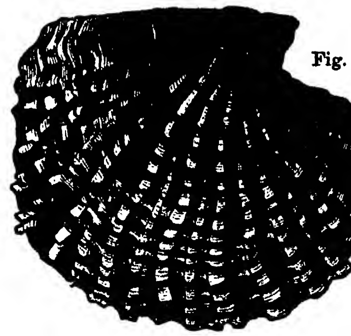


Fig. 7.

The *byssus*, or fasciculus of shining semi-transparent horny or silky filaments, by which many kinds of bivalves attach themselves to rocks, is in the large *Pinna* or wing-shell (Fig. 5) so much developed, that by the natives of Sicily it is manufactured into gloves, socks, caps, etc., of a beautiful brownish colour. These are valuable as objects of curiosity, but too expensive for general use, the price of a pair of gloves being six shillings, and that of a pair of stockings eleven shillings.

The large proportion of lime in shells renders them useful in making cement, and valuable as a fertiliser of the soil; and for this reason shell-sand, the product of their natural crumbling on sea-shores, is employed with advantage in improving heavy loams and clayey or peaty soils. Mixed with any soil deficient in lime, shell-sand exercises a beneficial influence.

If we look at a shell we shall find it to consist of three layers, viz., one external and rough, a medium layer consisting of delicate super-imposed laminæ of polygonal prisms, and an internal and shining one called the nacre, which is composed of a series of extremely delicate deposits, unequal in size and extent, and therefore imbricated in their position on each other, their margins presenting a series of lines with waved edges These wrinkles, or furrows, which are of microscopic proximity and minuteness, decompose the rays of light, and produce that beautiful iridescent play of colours visible on the surface of the shell. It is this nacreous lustre which renders shells so capable of being applied to ornamental purposes, and gives to them their principal commercial importance.

The brilliancy of the colours reflected depends on the thinness of the laminæ of the nacre. Where the laminæ are thick, a dull white appearance only is visible, as in the oyster. Sometimes the external layers covering the nacre are rubbed off by natural causes, as in the case of shells which have been subjected to the roll of the waves on the sea-shore, where quantities may be found having the bright and iridescent nacreous surface exposed, but more or less injured; generally, however, these outer layers are removed artificially with a knife, and the shell is polished. This nacreous layer is the well-known mother-of-pearl, and shells having it in the greatest abundance are called pearl shells, such as the sea-ears (*Haliotis*) and a large species of top-shell (*Turbo marmoratus*, L., Fig. 6). Mother-of-pearl, in consequence of its lamellar structure, admits of being split into laminæ; or it is cut, without being split, into square, angular,

or circular pieces, which are employed extensively in the arts, particularly in inlaid work and in the manufacture of knife- and razor-handles, buttons, snuff-boxes, and toys. Cut into the form of leaves, flowers, and other devices, it forms a favourite material for ornamenting *papier-mâché*—a name given to articles manufactured from paper pulp, which is moulded into varied forms, and rendered as hard as wood by being dried in an oven.

The most valuable shells in commerce are, however, those which form the nacre into the fine, compact, concentric layers called pearls. These pearls are sometimes found free within the lobes of the mantle, but most frequently adhere to the nacreous coat of the shell. The species which produces the largest and most valuable pearls is the

Pearl Oyster (*Meleagrina margaritifera*, L., Figs. 7, 8).—The most valuable pearl fisheries are those on the western coast of Ceylon; at the Bahrein Islands in the Gulf of Persia; at Tuticoreen, on the coast of Coromandel; off St. Margarita, or Pearl Islands, in the West Indies; in some places on the coast of Colombia; and in the Bay of Panama in the Pacific. Very large and beautiful pearls, too, are said to have been found recently on the peninsula of California. The fisheries in the Persian Gulf are the most valuable, giving employment to 4,000 boats and about 30,000 people, and yielding a revenue of more than 2,500,000 thalers (£375,000) a-year.

The value of pearls depends upon their size, purity, and lustre. The best are spherical, free from spot or stain, and have a clear, bright, white or yellowish-white, or bluish colour, with a peculiar lustre or iridescence. They vary in size—some not bigger than small shot, and others as large as a pea or bean. When pearls dwindle to the size of small shot, they are called seed-pearls, and are then of little value. "A handsome necklace of Ceylon pearls, as large as peas, is worth from £170 to £300; and one of pearls the size of peppercorns may be had for £15."* The largest and most valuable pearl of which we have any authentic account was purchased by Tavernier, at Catifa, in Arabia—a fishery famous in the days of Pliny—for the enormous sum of £10,000. It was pear-shaped, two inches in length, and half an inch in diameter, and is now the property of the Shah of Persia. The finest pearls generally pass under the name of "Oriental pearls;" and those with less lustre and beauty, even if they do come from the East Indies, are called "Occidental pearls."

Pearls are most abundant in the pearl oyster, which appears to be subject to a disease, caused by the introduction of foreign bodies within the shell. A pearl, if cut through, will generally show a nucleus, formed by a grain of sand or some other foreign body, around which the nacreous matter has accumulated in concentric deposits, instead of being spread in the usually horizontal laminæ on the inside of the shell.

The value of pearls has been greatly depreciated in modern times through the successful imitation of them. The spurious glass and wax pearls now made in Paris, Venice, Nuremberg, and Bohemia have much diminished the trade in real pearls. The best imitations were first made by a French bead-maker named Jacquin. The water in which the fish called the bleak (*Alburnus lucidus*) is washed, is filled with powdery particles, which shine with a pearly lustre. Jacquin noticed this; he called this powder "essence of pearl," or "*essence de l'Orient*," and succeeded in covering the inside of glass beads with it, thus producing a most admirable spurious glass pearl. A considerable trade is done with spurious pearls on the coasts of Senegambia, Guinea, and Congo, and the adjacent islands, where they are indispensable goods for the transaction of business with the natives.

NOTABLE INVENTIONS AND INVENTORS.

VI.—THE MARINER'S COMPASS.

THE contrivance by which the magnet, in the very middle of a strip of iron, is still true to the distant pole, and remains a faithful guide to mariners, is the compass, before the invention of which—

> "Rude as their ships was navigation then,
> No useful compass or meridian known;
> Coasting, they kept the land within their ken,
> And knew no north but when the Pole-star shone."

If we hang up a magnet by a thread, or allow it to swim in quicksilver, or place it in a small bit of wood floating in water, it never comes to a state of rest until one end points to the north and the other to the south. The needle or index of a compass is a prismatic piece of tempered steel, which, by having been rubbed on a magnet, has acquired a magnetic power, and which, being placed on a pivot, is at liberty to turn in all directions.

This accidental discovery of the property of a natural substance rapidly influenced the fortunes of mankind. "In the development of the commercial spirit of the Crusades, Providence is seen in its most manifest footsteps. Sitting upon the floods, it opens to new enterprises. The compass, twinkling on its card, was a beam from heaven; that tiny magnet was given as a seigniory of earth and sky. Like a new revelation, the mysteries of an unknown world were unveiled; like a new illapse, the bold and noble were inspired to lead the way. Diaz doubles the Cape of Storms; Da Gama finds his course to the East Indies; Columbus treads the Bahamas; and twelve years do not separate these discoveries."

The compass was the invention; the discovery which preceded it—for there must be a discovery preceding every invention—was the finding of the natural magnet or loadstone; and "this did more for the supplying and increase of social commodities than those who built workhouses," as said the grave philosopher, John Locke. The power of the loadstone to attract iron was known to the ancient Egyptians, who, however, did not apply it to any practical purpose. It is referred to by Aristotle and by Pliny, who tell us that ignorant persons called it quick-iron; and in the Middle Ages it was believed to possess medicinal properties, as an alterative and cure for sore eyes. Tiger Island, at the mouth of the Canton river, in China, consists chiefly of magnetic ore, and mariners say that the needles of their compasses are much affected by their proximity to the island. Tradition extends the story to drawing the nails and iron bands from the planks of ships, and thus causing them to fall to pieces; and it is remarkable that Chinese writers place the above magnetic island precisely in the region of the story of the voyages of Sindbad the sailor.

At what period the *polarity* of the magnet, or its disposition to turn to the north and south poles of the earth, was first discovered is not known. The Chinese appear to have known it from a very remote date, and to have extended it through most of the leading countries of Asia; the magnetic compass being used on land service prior to service at sea. Extracted from the Szuki of Szumathsian, a Chinese historian contemporary with the destruction of the Bactrian empire by Mithridates I., we find the following extraordinary relation: "The Emperor Tchwingwang, 1,110 years before our own, presented to the ambassadors of Tong-king and Cochin-China, who dreaded the loss of their way back to their own country, five magnetic cars, which pointed out the south by means of the moving arm of a little figure covered with a vest of feathers" "To each of these cars, too, a hodometer, marking the distance traversed by strokes of a bell, was attached, so as to establish a complete dead reckoning." (Humboldt's "Cosmos.") "A thousand years before our era, in the obscure age of Codrus, the Chinese had already magnetic carriages, on which the movable arm of the figure of a man continually pointed to the south, as a guide to find the way across the boundless grass-plains of Tartary; nay, even in the third century of our era—therefore at least 700 years before the use of the mariner's compass in the European seas—Chinese vessels navigated the Indian Ocean under the direction of magnetic needles pointing to the south. Klaproth has collected from Chinese authorities many curious anecdotes of the use of those chariots. Under the Tsin dynasty they formed a part of every royal procession. Whatever was the position of the car, the hand of the prism always pointed to the south. When the emperor went in state, one of these cars headed the procession, and served to indicate the cardinal points. The magnetic wagons or cars were made as late as the fifteenth century; several of them were carefully preserved in building the Buddhist monasteries, in fixing the points towards which the main sides of the edifice should be placed. Humboldt mentions the circumstance, that the magnetic land car used in China had attached to it a way measure. Over the trackless land, they were more certain of their course than the seaman of this age, who imperfectly ascertains the speed of his vessel by the log-

* See *Pearls*, "Dictionary of Commerce," by J. R. M Also "Journal of the Society of Arts," No. 896, Vol. XVIII.

line, is uncertain of his leeway, and has to correct all by the observation of the heavenly bodies for his latitude and for his longitude, the time by a watch showing the difference of noon at his place of observation and the port from which he started." Thus writes Mr. Buckton to "Notes and Queries," 3rd Series, No. 257, adding: "Mr. Scoresby (afterwards a clergyman) was the owner and master of a ship in the North whale-fishery from Liverpool. In a lecture delivered by him thirty-four years ago, he exhibited an important experiment, which does not appear to be generally known. He took a bar of iron two or three feet long, about one inch in diameter, and placing it in the direction of the magnetic meridian—that is, pointing to the north, at an angle of 40° or 50° with the horizon—he struck it a smart blow with a heavy hammer, by which from a simple bar of iron it became a magnet. Afterwards he placed the same iron bar in a direction at right angles to its former position, and striking it as before, its magnetism was thereby discharged, and it was proved to have none of the properties of a magnet. At the time I considered this a favourable illustration, although not so designed by Scoresby, of the magnetic theory of Euler, disclosed in his 'Letters to a German Princess.'"

The history of the compass in Europe has been much controverted. The twelfth century is assigned as the period of its introduction into Europe; but it does not appear to have been then brought into common use for nautical purposes. Though passages of various dates speak explicitly of the use of the compass for land purposes, yet no mention of the magnet for *navigation* occurs, in any Chinese books that have come to the knowledge of Europeans, till the dynasty of Tsin, which lasted from the year 265 to 419 A.D. It is in the great dictionary, Roi-wen-you-fou; and it is there stated that "there were then iron ships directed to the south by the needle." Sir John Davis contends that this passage rather refers to the magnitude of their ships, and the extent of the voyages which they performed, than to the introduction of the needle into marine affairs. In the ninth century two Mahometan travellers are stated to have traded in ships to the Persian Gulf and the Red Sea, and though the *compass* is not mentioned, it is utterly improbable that the Chinese should have known the directive property of the magnet, and have used it on land in thirty centuries, and yet not have employed it at sea.

It was known on the Syrian coast before it had come into general use in Europe, as is obvious from a passage in a manuscript written in 1242, which thus describes the natural compass: "We have to notice, among the other properties of the magnet, that the captains who navigate the Syrian sea, when the night is so dark as to conceal from view the stars which might direct their course according to the position of the four cardinal points, take a basin full of water prepared for the purpose by placing it in the interior of the vessel; they then drive a needle into a wooden peg or acorn-stalk, so as to form the shape of a cross, and throw it into the basin of water prepared for the purpose, on the surface of which it floats. They afterwards take a loadstone of a sufficient size to fill the palm of the hand, or even smaller, bring it to the surface of the water, give to the hands a rotatory motion towards the right, so that the needle turns to the water's surface; they then suddenly and quickly withdraw their hands, when the two points of the needle face north and south. They have given me ocular demonstration of this process during our sea-voyage from Syria to Alexandria in the year 650 of the Hegira." When we consider the jealousy with which all knowledge was guarded by its possessors, especially that of *commercial* value, we cannot but admit that the use of the compass must have been very common at a period when a passenger was initiated into the complete knowledge of the mode of magnetising the steel needle, as well as the mode of using it.

About 1260, according to Dante's teacher, the needle was highly useful at sea, but the navigators were prejudiced against its adoption; for, says he, "no master-mariner dares to use it, lest he should fall under the suspicion of being a magician; nor would even the sailors venture themselves out to sea under his command, if he took with him an instrument which carries so great an appearance of being constructed under the influence of some infernal spirit." Dante refers, in a simile, to "the needle which points to the star;" and Raymond Lully, in 1286, remarked that the seamen of his time employed "instruments of measurement, sea-charts, and the magnetic needle."

The earliest mention of the primitive mariner's compass in English records is that in a work by Alexander Neckham (b. about 1150), entitled "Treatise on Things pertaining to Ships." In the reign of Edward III. the magnet was known as the Sail-stone, or Adamant, and the compass was called the Sailing-needle, or Dial; though it is long after this period that we first find the word *compass*. Chaucer, who died in 1400, mentions the compass and the sailors reckoning thirty-two points of the horizon, which is the present division of the card. Dr. Gilbert, physician to Queen Elizabeth, and who bestowed much attention upon magnetism, compared the earth to *a great magnet;* and in our time Faraday said, "The earth is a great magnet; its power, according to Gauss, being equal to that which would be conferred if every cubic yard of it contained six one-pound magnets; the sum of the force is, therefore, equal to 8,464,000,000,000,000,000,000 such magnets." The use of the word *compass* had become familiar in the reign of Charles I., and Rowe, in his Play of "Jane Shore," speaks of "the seaman's compass."

Sir John Ross, during his last voyage in the *Felix*, when frozen in about 100 miles north of the magnetic pole, concentrated the rays of the full moon on the magnetic needle, when he found it was five degrees attracted by it. A curious notion has been current, more especially on the shores of the Mediterranean, that if a magnetic rod be rubbed with an onion, or brought into contact with the emanations from that plant, the directive force will be diminished, while a compass thus treated will mislead the steersman. "It is difficult," says Humboldt, "to conceive what could have given rise to so singular a popular error." ("Wonderful Inventions," 1868.)

TECHNICAL DRAWING.—XXI.

DRAWING FOR MACHINISTS AND ENGINEERS.

FIG. 215.—The subject of this lesson, based on a study in Professor Bradley's excellent large work, is a *dead-beat anchor escapement*. The escapement wheel would carry the seconds hand of an astronomical clock.

The pallets are shown in two positions, when the pendulum has vibrated through one arc.

Draw the circles A and B, and divide A into the number of equal parts corresponding with the number of teeth required.

From each of these points draw lines touching the circumference of the circle B, as shown by the lines C D and E F.

Draw the circle G, and with the radius divide it into six equal parts: the radii drawn from these will be the centre lines for the arms

Now from the points of the teeth draw tangents to the circle G, as shown in the lines H J and I K.

The lines H J and I K will cut the lines C D, and the other faces of the teeth, in points L, M. etc., all of which will be situated on the circle, and thus C L will be the depth of the face of the teeth.

The line H J, etc., will also give the upper part of the backs of the teeth, as H O, the length of which is fixed by the circle O.

The remaining portion of the backs of the teeth is drawn as shown in another tooth.

From P and Q, with any convenient radius, describe arcs cutting each other in R; then from R describe the arc P Q.

The student is again reminded, that to find the centre from which any arc of a circle is struck, three points are to be marked on the arc, and the lines uniting them are to be bisected; the intersection of the bisectors will then be the centre of the arc.

On each side of S set off S T and S U, for the width of the arms at their upper end.

Draw the circle V, and from W set off W X and W Y, for the width of the arms at their lower end.

Draw T Y and U X for the edges of the arms; but as these arms do not run as straight lines into the rim, but are connected by curves, the lines must only be fully drawn from t to Y and from u to X.

The distance t T may be carried round to each of the arms by a circle. On this circle set off t T′ equal to t T, and from T′, with radius t T′, draw the arcs connecting the edges of the arms with the inside of the rim.

The arms are connected at the bottom by circles of any convenient radius, as shown in the drawing at Z and Z′.

The anchor in its first position is an arc drawn from 1, whilst in its second position the arc is struck from 2.

The remaining portion of the drawing is left to the student's knowledge; and this plan will be constantly adopted, in order to release him as soon as possible from leading-strings, and by throwing him more and more on his own resources, give him

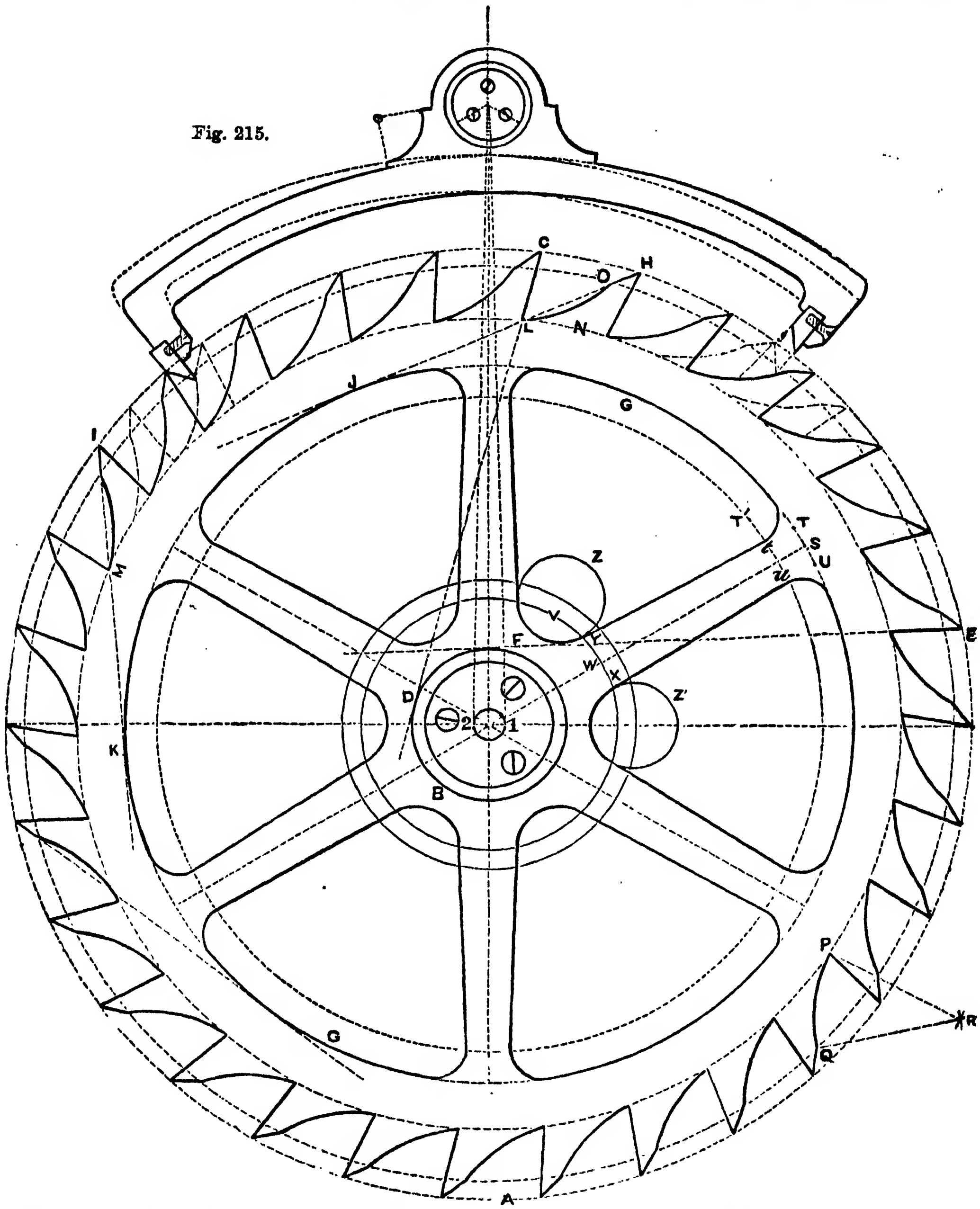


Fig. 215.

the opportunity for exercise of thought and ingenuity, with the conviction that each success will give confidence, and inspire him with the desire for further exertion.

Fig. 216 is the front, and Fig. 217 is the side elevation of a *crank*, to draw which the student will require but few instructions. The centre line, A B (Fig. 216), is to be drawn first, and a horizontal line having been drawn at A, the distances A C, A D, A E, A F are to be set off, and perpendiculars drawn from them. The distances of the other perpendiculars are to be set off from the centre line. This plan is to be universally adopted.

It is unwise to set off points from each other, for if either one be at all inaccurate, the error is carried on throughout the work, whereas if all the distances are set off from a centre line, any error will be confined to any one point which may have been inaccurately measured.

For the same reason the horizontal line G H is to be drawn, and on each side of this half the widths of the end of the crank, the crank-pin, etc., are to be set off.

In Fig. 217 the distance from centre to centre, A B, is to be first marked, and from these the different concentric circles are to be described.

The lines C D and E F are next to be drawn near the circles at right angles to A B. On these the widths of the crank are to be marked, and the lines C E and D F are to be drawn. The subject will now be easily completed.

Unless formed in one complete forging, the crank, however

important in machinery, labours under the disadvantage of requiring the shaft to be divided, as shown at I and J in Fig. 216, unless when placed at the end; and therefore, when a crank of a small throw is wanted, as in the mechanism for moving the slide-valves of a steam-engine, the eccentric may be substituted brass or gun-metal for the purpose of diminishing friction, is accurately fitted within projecting ledges, D, on the outer circumference of the eccentric, so that the latter may revolve freely within it. This ring is connected by a rod, E, with a system of levers by which the valve is moved.

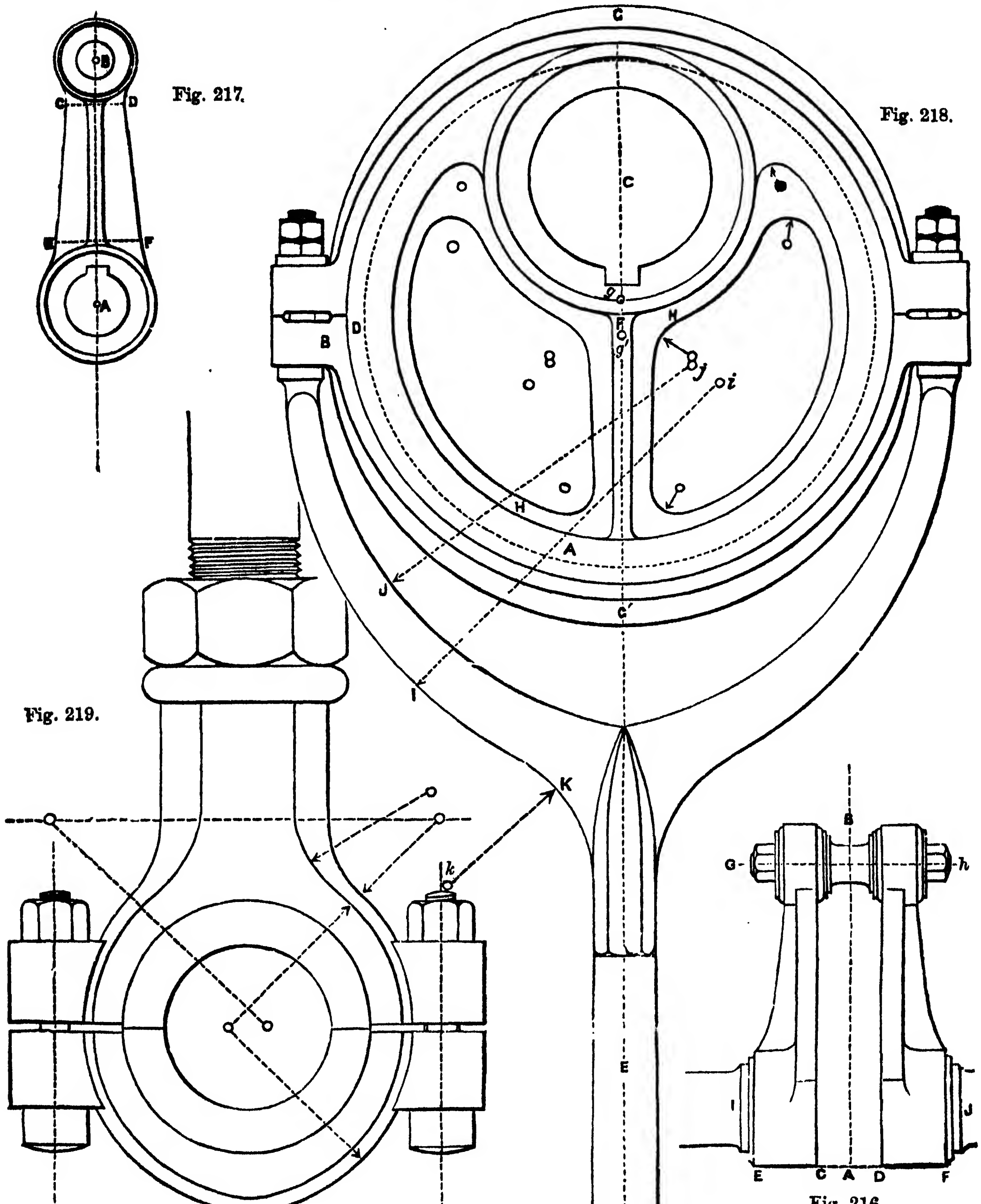


Fig. 217.

Fig. 218.

Fig. 219.

Fig. 216.

for the crank. This will be further elucidated in another lesson. In the *eccentric* (represented on a larger scale in Fig. 218) a circular plate, A, is surrounded by a hoop, B, the plate being movable about the centre of motion at C.

"The circular eccentric is simply a species of disc or pulley, fixed upon the crank-shaft, or other rotating axis of an engine, in such a manner that the centre or axis of the shaft C shall be at a given distance from the centre of the pulley.

"A ring or hoop, either formed entirely of or lined with

"It is evident that as the shaft to which the eccentric is fixed revolves, an alternating rectilinear motion will be impressed upon the rod, its amount being determined by the eccentricity, or distance between the centre of the shaft, C, and that of the exterior circle.

"The *throw* of the eccentric is twice the eccentricity of C F, or it may be expressed as the diameter of the circle described by the point F.

"The nature of the alternating motion generated by the

circular eccentric is identical with that of the crank, which might in many cases be advantageously substituted for it."—*Le Blanc and Armengaud.*

In commencing to draw this example, describe the circles for the hoop, from the centre F. This hoop, which is made in two portions, united by bolts and nuts, is strengthened by flanges, G and G′, the arcs of which are struck from the centres *g* and *g*′ a little above and below the centre, F.

The end of the shaft, C, and the circles surrounding it, are now to be drawn; then the arm, and subsequently the web, H H. In order to guide the student in joining the curves, the centres of the arcs by which they are united are marked, and he is urged to work with the utmost care and accuracy, so that the curves may flow gracefully into each other. The double nuts are next to be drawn.

The fork of the rod is formed by three arcs. The arc I has its centre at *i*, and this is continued by an arc, K, turning in the opposite direction, drawn from *k*. The inner arc, J, is struck from *j*. The rest of the figure will now be easily drawn without further instructions.

Fig. 219.—This figure represents one of the ends of the *valve-rod of a marine engine.* The centres from which all the arcs are drawn are shown, and the whole object being of a very simple form, is left for the student to draw without further aid.

For by this time the student who has diligently and intelligently followed our instructions from the very beginning will no doubt think himself able to bear a certain degree of independence, and it is our desire to encourage such a healthy sentiment, within reasonable limits of course. Other things being equal, the sooner the student feels his feet the better.

TECHNICAL EDUCATION AT HOME AND ABROAD.

I.—AID AFFORDED BY THE DEPARTMENT TO INSTRUCTION IN ART—NATIONAL ART SCHOOL.

BY SIR PHILIP MAGNUS.

SPECIAL classes were started at Marlborough House for the training of designers for textile fabrics of all kinds, for metal work, porcelain painting, wood engraving, etc. In 1857 the school was removed to South Kensington, where the instruction is now carried on, the teaching having been developed on more general lines than was originally intended. Very recently, however, a more technical direction has been given to the art instruction, with the special object of training trade designers rather than mere picture painters. Between the year 1851 and the present time, successive efforts have been made to encourage, by means of grants, the teaching of drawing in elementary schools, which is the first step towards the popularising of any system of technical education. To what extent these efforts have proved successful may be inferred from the statistics adduced in a former chapter, from which it appeared that a large proportion of the children in attendance at public elementary schools did not learn drawing. The progress made, however, during the last few years has been considerable. For it appears from the official returns that in the year 1872, drawing was taught to 194,549 children, in 1,773 elementary day schools, and that in the year 1886, the corresponding numbers were 870,491 children under instruction in 4,446 schools. It was probably owing to the insufficient training in elementary drawing and modelling, which the students seeking to become designers had received, that the Department was unable to give effect to its original programme of providing technical instruction in different branches of ornamental art. In order to make the teaching of drawing an essential part of elementary instruction, it is necessary that it should rank as an obligatory subject with reading, writing, and arithmetic; and the Royal Commissioners on Technical Instruction issued a recommendation to this effect. But drawing has not yet become a compulsory subject, notwithstanding the recommendation of the highly competent body mentioned.

If young persons engaged in manufactures come to the evening art schools after having received some elementary instruction in drawing and possibly in modelling also, and with a knowledge of the capabilities of the material in which they have to work as acquired in the shop or factory, they will very readily be able to apply their knowledge to the production of original and suitable designs; and the great advantage of making instruction in drawing general is that whilst every pupil will derive some benefit from it, the opportunity will be afforded at an early period of the children's education of selecting for more advanced teaching those who exhibit any decided taste or aptitude for art instruction.

Aid is now given by the Department towards promoting art instruction in elementary day schools and in training colleges for the teachers of elementary schools; in art classes for young persons above twelve years of age, and older students of the industrial classes; and in schools of art, in which students can go through a complete course of art instruction.

Payments varying from ten shillings to three pounds are made to the committees of art classes on account of each exercise worked by a student, under given conditions, provided that the teacher of the class has given not less than twenty-eight lessons. Prizes are also given to the students. In schools of art, which are defined as "rooms devoted wholly to instruction in art," payments are made to the local committee on account of artisans or apprentices varying from ten shillings to ten pounds according to the character of the work examined. In order to encourage modelling of an elementary character, examiners are sent to towns where classes are carried on to hold an examination on the spot, with a view of saving the cost of transmitting works to London. Additional payments are now made on account of students who have attended at least forty lessons in modelling. This further assistance to the teaching of modelling will undoubtedly encourage instruction in this subject, which has hitherto been far more generally taught in other countries than in our own. Grants in aid of the establishing and equipping of schools of art are given by the Department on conditions similar to those on which such grants are given for science schools. The lien of the Department on art examples purchased with its aid is determined after five years' continuous use of the examples, which then become the absolute property of the school.

Corresponding to the Normal School of Science is the National Art School for the training of art teachers.

The course of instruction comprises the following:—

Stage I. Linear Drawing by aid of instruments.—(*a*) Linear Geometry. (*b*) Mechanical and Machine Drawing (from the flat, from blackboard lessons, or from elementary solids or details of machinery and building construction). (*c*) Linear Perspective. (*d*) Details of Architecture from copies. (*e*) Sciography.

Stage II. Freehand outline drawing of rigid forms from flat examples or copies.—(*a*) Objects. (*b*) Ornament (showing elementary principles of design).

Stage III. Freehand outline drawing from the "round."—(*a*) Models and Objects. (*b*) Ornament.

Stage IV. Shading from flat examples or copies.—(*a*) Models and Objects. (*b*) Ornament.

Stage V. Shading from the "round" or solid forms.—(*a*) Models and Objects. (*b*) Ornament. (*c*) Drapery. (*d*) Time sketching and sketching from memory.

Stage VI. Drawing the human figure and animal forms from copies.—(*a*) In outline. (*b*) Shaded.

Stage VII.—Drawing flowers, foliage, and objects of natural history, from flat examples or copies.—(*a*) In outline. (*b*) Shaded.

Stage VIII. Drawing the human figure or animal forms from the "round" or nature.—(*a*) In outline from casts. (*b*) Shaded. (*c*) Studies of the human figure from nude model. (*d*) Studies of *drapery arranged on figure from antique or on the living model.* (*e*) Time sketching and sketching from memory.

Stage IX. Anatomical studies.—(*a*) Of the human figure. (*b*) Of animal forms. (*c*) Of either, modelled.

Stage X. Drawing flowers, foliage, landscape details, and objects of natural history, from nature.—(*a*) In outline. (*b*) Shaded.

Stage XI. Painting ornament from flat examples. (*a*) In monochrome, either in water-colour, tempera, or oil. (*b*) In colours, either in water-colour, tempera, or oil.

Stage XII. Painting ornament from the cast, etc.—(*a*) In monochrome, either in water-colour, oil, or tempera.

Stage XIII. Painting (general) from flat examples or copies, flowers, still-life, etc.—(*a*) Flowers or natural objects in water-colour, in oil, or in tempera. (*b*) Landscapes, or views of buildings.

Stage XIV. Painting (general) direct from nature.—(*a*) Flowers, or still-life, in water-colour, oil, or tempera without backgrounds. (*b*) Landscapes, or views of buildings. (*c*) Drapery.

Stage XV. Painting from nature groups of still-life, flowers, etc., as compositions of colour.—(*a*) In oil colour. (*b*) In water-colour or tempera. (*c*) *In monochrome or light and shade.*

Stage XVI. Painting the human figure or animals in monochrome from casts.—(*a*) In oil, water-colour, or tempera.

Stage XVII. Painting the human figure or animals in colour. —(*a*) From the flat, or copies. (*b*) The Head from nature, or draped figure. (*c*) The nude figure from nature. (*d*) Time sketches.

Stage XVIII. Modelling ornament.—(*a*) Elementary, from casts. (*b*) Advanced, from casts. (*c*) From drawings. (*d*) Time sketches from examples and from memory.

Stage XIX. Modelling the human figure or animals.—(*a*) Elementary, from casts of hands, feet, masks, etc. (*b*) Advanced, from casts or solid examples. (*c*) From drawings. (*d*) The head from nature. (*e*) The nude figure from nature. (*f*) Drapery.

Stage XX. Modelling fruits, flowers, foliage, and objects of natural history, from nature.

Stage XXI. Time sketches in clay of the human figure, or animals, from nature.

Stage XXII. Elementary design.—(*a*) Studies treating natural objects ornamentally. (*b*) Ornamental arrangements to fill given spaces in monochrome or modelled. (*c*) Ornamental arrangements to fill given spaces in colour. (*d*) Studies of historic styles of ornament drawn or modelled.

Stage XXIII. Applied designs, technical or miscellaneous studies.—(*a*) Machine and mechanical drawing, plan drawing, mapping, and surveys done from measurement of actual machines, buildings, etc. (*b*) Architectural design. (*c*) Ornamental design as applied to decorative or industrial art. (*d*) Figure composition, and ornamental design with figures, as applied to decorative or industrial art. (*e*) The same as 23*c*, but in relief. (*f*) The same as 23*d*, but in relief.

Facilities are offered to teachers in training to receive instruction in this school. Under certain conditions they receive gratuitous instruction and a weekly stipend of 20s. to 40s. during the period of their study. Students who are already engaged in designing for, or in producing, works of art manufacture are considered as the most eligible for these scholarships, which are intended to enable advanced students to prosecute their studies in London with a view to their returning to practice in the seats of manufacture.

THE INDUSTRIAL ART MUSEUM.

The influence of the Department in promoting art teaching, in encouraging design, and in improving the taste of the people, cannot be fully estimated without reference to the Industrial Art Museum of South Kensington, and to the system of circulating in the manufacturing centres objects of art and books. The South Kensington Museum constitutes one of the most important educational instruments which this country possesses. It is regarded almost everywhere abroad with interest and with admiration. Foreign commissions have been appointed to visit it and to enquire into its organisation, and these commissions have generally resulted in recommendations for the establishment of similar museums abroad. In Paris efforts are being now made to found an art museum on the mode of our own. A commission that sat in Brussels, presided over by M. Buls, reported a short time since in favour of the establishment of such a museum in that city. No educational institution we possess is better known or more highly and more justly appreciated abroad than our South Kensington Museum. Time was when the foreigner's idea of London was restricted to the Thames Tunnel or the Tower, which he believed to be the objects of great interest to all Englishmen; but now-a-days the South Kensington Museum is equally well known, and one often hears foreigners, who are actively engaged in the working of institutions that have for their object the advancement of technical education, lament the absence from their own country of anything corresponding, in the extent and value of its collections, to "South Kensington." If we would see ourselves as others see us, we might sometimes find that we have merits which we have not learnt sufficiently to value.

The influence of museums on the development of taste and in enabling people to appreciate and to produce beautiful objects has only recently begun to be understood. It has been already remarked that the superiority of the French and of the Italians over ourselves in artistic skill is mainly due to the beautiful objects, natural and artificial, by which these people have been long surrounded. The display of tasteful articles in the shops of Paris has had much to do with the making of Paris the city of industrial designers. The fact that in France, in Italy, in Belgium, and in other countries, the museums, the picture galleries, and many of the palaces are open on the Sunday, and that they are largely visited on this day by work-people and their families in bad weather, or when the heat is too great for the enjoyment of out-door exercise, has had, and continues to have, a powerful influence in refining the taste of these people, and indirectly in sweetening their lives, by lifting them out of their ordinary surroundings into a world of beauty created by human labour. But a museum like that at South Kensington not only presents to the eye beautiful objects which must please and insensibly affect the most superficial observer; but it shows to the more inquiring mind the history of the progress of art, and illustrates the gradual advances that have been made as difficulties of various kinds have been successively overcome. It is in the variety, in the completeness, and in the arrangement of its exhibits, that a museum serves the purpose of an educational institution. The museum at South Kensington is at once an exhibition and a school.

CIRCULATION OF WORKS OF ART.

A very useful and important branch of work connected with the South Kensington Museum is the loan of works of art to provincial museums and art schools. Whilst it is very desirable that the central museum should be situated in the metropolis, it is equally important that the collections of beautiful objects which the museum possesses should be exhibited in other great centres of industry, so as to be available for the instruction of the artisans of all parts of the country. The authorities of the museum have accordingly organised a system for the circulation of objects of art and of books, suitable for exhibition in local museums and art schools in connection with the Department or under the Public Libraries Act. Selections may be made from the classes above mentioned according to the special requirements of any locality. These loans are made under certain conditions prescribed by the Department with the view of securing the objects lent from damage, and of insuring the ready access of artisans to these exhibitions. Thus, one of the conditions laid down in the Art Directory with respect to these loans is that: "Artisans being students of the school must be admitted free; but all other persons should pay a moderate fee for admission. To enable artisans, not students in the school, and others employed in the day-time to share the benefits to be derived from the collection, the fee on two evenings in the week is not to exceed one penny each person."

BUILDING CONSTRUCTION.—XI.

STONE ARCHES—WOODWORK, ETC.

THE simplest form of arch—viz., the semi-circular—may be considered as the half of a cylinder, and this knowledge will materially assist the student in projecting the different forms now required. The subject of cylinders, their sections and developments, having been fully treated in "Projection" (see Lessons IX. and X., pages 204, 235), it will only be necessary here to apply the principles there laid down.

Let A B D C (Fig. 75) be the plan of a road to be crossed by a bridge, the arch of which is semi-circular. It must, however, at the outset, be explained that an elliptical or any other form of arch would be projected in an exactly similar manner, the semi-circular being merely chosen in this case as simplest for the present purpose.

Now if the arch were to cross the road at right angles to its sides, A B, C D, the elevation would be that drawn as at E F (Fig. 76), and, of course, any section taken at right angles to the sides would be of the same form, the arch being perfectly semi-circular.

The development of the soffit—that is, the shape of the covering of the interior of the arch—would in that case be a parallelogram, whose width would be equal to the depth of the arch, and whose length would be equal to the curve forming the semi-circle E F, and its plan would be the rectangle H I K L.

But, in the present study, the arch crosses *obliquely*, its elevation making an angle of 60° with the side of the road, C D. The plan of the bridge then becomes the rhomboid G H I J, instead of the rectangle H I K L.

The construction necessary for the proper projection of the arch under these circumstances, so as to find its exact shape, is an application of the study given in lessons in "Projection;" for it will be seen that the arch must be treated as a *semi-cylinder*, and the elevation as a section of it at an angle of 60°.

Having drawn the elevation (Fig. 76) as it would be if it crossed at right angles to the roadway, and having divided it into its voussoirs, the joints of which converge to the centre, draw lines perpendicular to E F from the points E, N, O, P, Q, R, S, F, meeting the line at which the arch really crosses in the plan of the arch (and here again the student is referred for elementary information to the figures in "Projection" already mentioned).

Produce the line L H indefinitely, and from the point H, which in Fig. 77 is coincident with E of Fig. 76, set off the lengths N, O, P, Q, R, S, F *from the original elevation*, in order to obtain the length of curve. But the student is reminded that this is only approximately correct, for it is measuring *chords* instead of arcs, and straight lines are, of course, shorter than curves, as a straight line is the shortest distance between any two points. In order, therefore, to approach as nearly as possible to the true length of a curve, it is desirable to divide it into numerous parts, by which the chords become shorter, and the difference between the curved and straight lines is lessened.

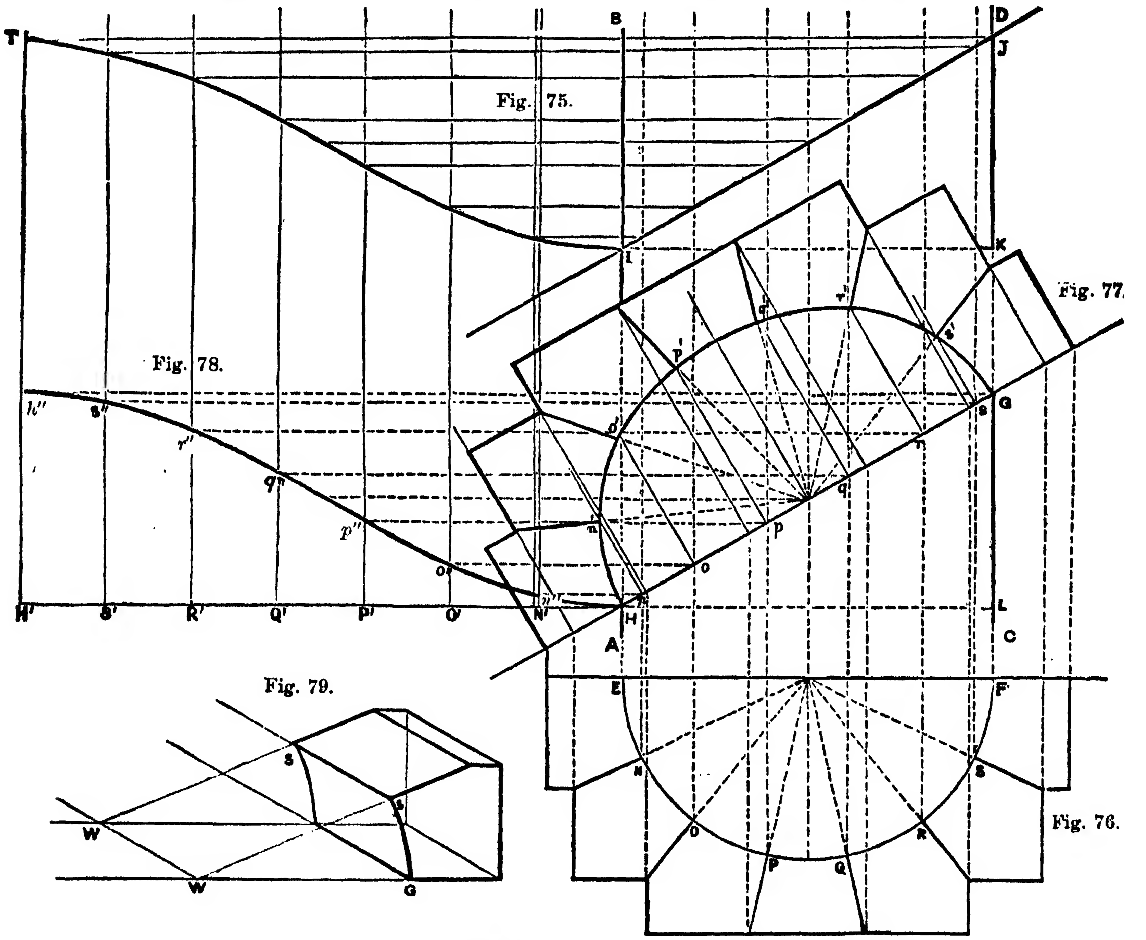


Fig. 75.

Fig. 77.

Fig. 78.

Fig. 79.

Fig. 76.

points H, *n*, *o*, *p*, *q*, *r*, *s*, G (Fig. 77). At these points draw lines perpendicular to H G.

Now the ground line G H (Fig. 77) corresponds with the ground line E F (Fig. 76); it is only longer because it crosses obliquely, and thus the perpendiculars, in consequence of this lengthening of the whole line, will be further apart than they are in the original elevation.

But although they will become further apart they will not be in any way altered in height; therefore mark on the perpendiculars *n*, *o*, *p*, *q*, *r*, *s*, the heights of the perpendiculars N, O, P, Q, R, S in the original elevation (Fig. 76), thus obtaining the points *n'*, *o'*, *p'*, *q'*, *r'*, *s'*.

The curve drawn through these points will give the true form of the required elevation, and is the shape for the centering on which the arch would be built, and of the templet used in shaping the separate voussoirs.

It will now be convenient, before too many lines crowd the paper, to work out the development of the underneath surface of the arch.

Divide, then, one of the spaces—viz., F S—into, say, four equal parts, and set these off from H on L H produced—viz., H H'. Now there are seven divisions in the intrados of the arch, and they are all equal; therefore set off from H the distances N', O', P', Q', R', S', H' equal to F S. The length H H' is thus the length of the curve.

From N', O', P', Q', R', S', H' erect perpendiculars, and intersect them by horizontals drawn from the points similarly lettered in the base line of the oblique elevation.

Through the points thus obtained—viz., *n''*, *o''*, *p''*, *q''*, *r''*, *s''*, *h''*—draw the curve H *h''*, and from them set off on the perpendiculars the lengths H I. Connect these points by the curve I T, and the figure H I T *h''* (Fig. 78) will be the development of the soffit of the arch.

To draw the outer edges of the voussoirs, proceed, precisely as before, to draw lines parallel to the axis of the cylinder, and at the points where such lines meet the base line of the oblique elevation, draw perpendiculars to G H. Mark on each of these

the heights taken from the base line in the original elevation, and the rest will be seen from the diagram.

Fig. 79 shows a simple projection of one of the voussoirs, the first on the left side. The face is, of course, drawn from the oblique elevation, the curve being struck from the templet already mentioned, which may for drawing purposes be cut out of a piece of veneer. If this is done, the student will easily be able to draw the portion of the curve required for each voussoir.

one is divided into five stairs called *winders*, whilst the straight stairs are called *flyers*.

To draw the winders, produce the lines forming the edges of the steps *b* and *c*, until they meet in A. Then from A, with radius A *b*, describe the quadrant connecting the lines *d c* and *a b*. The same radius will also give the quadrant at the opposite end. From A with any radius describe the quadrant B, and divide it into five equal parts; through these points draw lines converging to A, which will complete the plan of the winders.

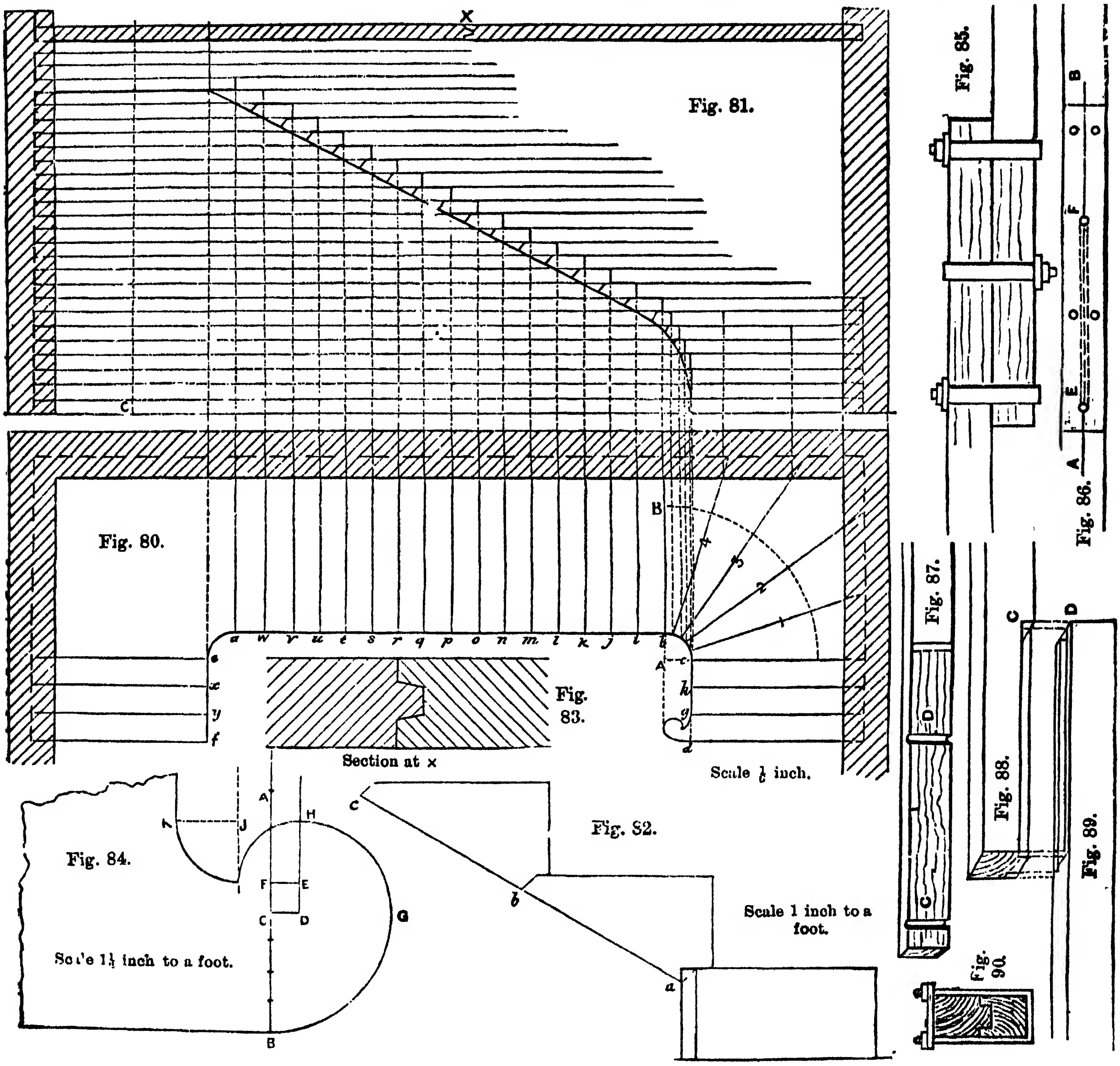


Fig. 80. Fig. 81. Fig. 82. Fig. 83. Fig. 84. Fig. 85. Fig. 86. Fig. 87. Fig. 88. Fig. 89. Fig. 90.

Produce the base and the slanting portion of the face until they meet in W. This wedge form will then correspond with that in the oblique elevation produced to the centre.

With the set-square of 30° draw the receding lines, and it will be evident that the distant edges are parallel to those in the front.

Fig. 80 gives the plan, and Fig. 81 the elevation, of a stone staircase, with detail to an enlarged scale.

Draw the walls of the plan, and from the inside lines of these draw the lines *a*, *b*, *c*, *d*, and *e*, *f*, equal to length of the steps from end to end. Mark off on these the *widths* of the steps, and draw the lines which will be the plans of the edges *d*, *g*, *h*, *c*; *b*, *i*, *j*, *k*, *l*, *m*, *n*, *o*, *p*, *q*, *r*, *s*, *t*, *u*, *v*, *w*, *a*; *e*, *x*, *y*, *f*. The quarter-spaces will still be left in the corners, and of these the

In the other corner there is really a quarter-space, and from this four steps rise, the last of which is the landing.

It will be seen that the steps are built into the wall. This is shown by the dotted lines in the plan. The lowest one also rests on the ground, and this supports the length of the one above it, and so on in succession, the stairs fitting in to each other by a joint called a "joggle," shown at *a*, *b*, and *c* in Fig. 82.

It is necessary here to mention that the flat surface of a stair is called the *tread*, and the upright face is termed the *rise*.

The slabs forming the passage seen in section in the elevation at X (Fig. 81) are joined as shown in Fig. 83. They, too, are built into the wall at their inner edge, and the passage is further supported by a cantaliver, not shown in this elevation.

Fig. 84 shows the mode of describing the curtail, or lowest step, drawn to the scale of 1½ inch to the foot.

Draw A B equal to the width of the visible portion of the tread of the step—namely, eleven inches by scale, an inch and a half being covered by the step above.

Bisect A B in C, and divide C B into four equal parts. On the bisecting line C construct the square C D E F, the sides of which equal any one of these four parts.

From C, with radius C B, describe the quadrant B G. From D, with radius D G, describe the quadrant G H; and from E the quadrant H I, which will complete the spiral.

From I draw a perpendicular, and make I J equal to I E. From J, with radius J I, describe the quadrant I K, and from K the straight end of the step will be drawn as shown in the general plan. The projection of the elevation of the steps is so simple that it will not require much explanation.

Having projected from the plan the mere sections of the walls supposed to be cut through, draw any perpendicular, as C, and on it set off the heights of the rises. This height is, of course, regulated by the room at the disposal of the architect, and the height of the floor to be reached: in this case an average height of rise is taken—that of six inches.

Letter each of these points to correspond exactly with the figuring of the edges of the steps on the plan. (It will be seen that, in order to avoid crowding, figures belonging to the winders are placed on the lines, instead of at their extremities.)

Now from the points marked in the perpendicular in the elevation draw horizontals, and from the points at the extremities of the edges of the steps in the plan draw perpendiculars; then the right angles formed by the intersections of the lines similarly lettered will be the end elevations of the stairs. All other guidance may be obtained by careful study of the diagrams.

WOODWORK: DRAWING FOR CARPENTERS AND JOINERS.

JOINTS IN TIMBER.

Before treating of what are usually termed joints, we must give some attention to the methods of uniting pieces of timber so as to increase their length, whilst achieving, as nearly as possible, the same amount of strength which the timber would have if it consisted of one piece only.

In writing on this subject, the author necessarily bases his observations on the principles laid down by such standard authorities as Tredgold, Robison, Thomas Young, Peter Nicholson, etc.; but he has also been guided in some degree by German and French practice. Some of the examples are culled from Continental sources, in order to give the student as extended a view of the subject as the limits of these lessons admit; and to the information thus gleaned he has added the results of his own experience, extending over many years.

The modes of joining timbers, so as to increase their length, are very numerous, and have most of them certain advantages when applied under particular circumstances. Some of the methods adopted are ingenious, but the simplest is generally the best. It will be clear that the method of joining shown in Fig. 85 must be the strongest that could possibly be adopted. Here two pieces of the same scantling* are laid over each other for a certain length, and then either held together by iron bolts or by bands. The author prefers the latter, because, by boring holes through the timber, the fibres are divided, and the strength of the beam thereby diminished. This, it is hoped, will be made clear by the following diagram.

Let us suppose ourselves looking down on a beam united as proposed, by placing the ends one over the other and bolting them together. Our view then would be that represented in Fig. 86.

Fig. 87 shows the section of the lower timber on the line A B, as it would be if bored for bolts, and in this it will be seen that the fibres are totally severed at C and D, and that the wood between the two bolt-holes cannot in any way contribute to the strength of the beam as far as its *length* is concerned, as it is only connected with it by its lateral cohesion.

This being understood, we return to the plan (Fig. 86), and here we shall see that, as the connection between the fibres at E and F has been severed by the bolts, the whole of the strip between them (shown in dotted lines) is rendered useless; and as this occurs three times in the beam, the only parts left in their natural strength are those not pierced by the bolts; and *these are not fastened together at all*. It is therefore necessary that iron plates should be placed over the parts to be joined, and by this means the whole may be held firmly together.

Now the system proposed by the author for joining beams of great length is shown in the following diagrams.

Figs. 88 and 89 show how a rebate is to be sunk in the one beam and a tongue left in the other. This form leaves a shoulder at C, against which the end D presses, thus affording security against compression from the ends, and preventing all chance of the beams sliding over each other.

Fig. 90 is a section showing the iron strap which forms three sides of a rectangle, the fourth being formed by a plate, which fits in the screws at the ends of the strap, and is secured by nuts. This allows of occasional tightening-up, if there should be any sagging owing to shrinking of the wood, etc.

* —The transverse dimensions of a piece of timber in breadth and thickness. Scantling is also the name of a piece of timber, as of quartering for a partition, or the rafter, pole-plate, or purlin of a roof. All quartering (the small timbers of which partitions are built) under five inches square is called *scantling*.

CHEMISTRY APPLIED TO THE ARTS.—VII.

BY GEORGE GLADSTONE, F.C.S.

SODA.

SODIUM (chemical symbol Na, from the latin word, *Natrium*), which is the metallic base of soda, is one of the commonest substances in Nature; though it never occurs as a metal, in consequence of its great affinity for the oxygen of the atmosphere.

What is most generally known as soda is a compound with carbonic acid. Another most familiar combination is that with chlorine, forming the common table salt. A third, which is not uncommon in Nature, and which is also largely manufactured, is sulphate of soda, or Glauber's salts. The other preparations of soda are of minor importance, and need not be mentioned.

It is the carbonate of soda (Na_2CO_3) with which we are specially to concern ourselves, as it is manufactured on a very extensive scale, employing a large number of hands, and contributing greatly to the prosperity of certain districts in England and Scotland. The borders of the river Tyne, below Newcastle, may be considered the head-quarters of the manufacture in England, though there are also some large works near Liverpool. In Scotland the principal establishments are situated in the neighbourhood of Glasgow.

Great changes have taken place in this branch of trade, and many of the sources of supply which were much valued formerly are now comparatively neglected. The plants which thrive on the sea-beach used to be collected and burnt for this purpose, as their ash contains a considerable per-centage of soda; and some kinds of sea-weed are also treated in the same way. In addition to the home supply of kelp from our own coasts, it used to be imported from France, Spain, the Canary Islands, and other places, under the name of *barilla*. Soda is now, however, made almost exclusively from other articles, very different in their character, and which can be obtained in almost unlimited quantities.

Common salt, sulphur, limestone, and coal are now the principal ingredients; and all these are, fortunately, very abundant in Nature. The sulphur is by far the most expensive, as it has for the most part to be imported from abroad, but the sources from whence it is obtained are multiplying so rapidly that the manufacturers can depend upon a regular supply at a much more reasonable price than formerly. Until very recently, the sulphur used in this country came almost exclusively from Sicily, and the supply with difficulty kept pace with the increasing demand. This led to the substitution of pyrites, a mineral consisting of sulphuret of iron or copper, the price of which was so much lower as to be more economical. Pyrites is now brought in very large quantities from Ireland, Spain, Portugal, and Norway, to Newcastle, Liverpool, and Glasgow, in order to furnish the great chemical works at these places with this necessary ingredient.

Common salt (the chloride of sodium) is the article from

which the soda of commerce is made. The first step is to convert it from a chloride to a sulphate. This may be done by roasting the salt in a furnace, along with sulphuric acid, by which means the chlorine, in the form of hydrochloric acid, is driven off, and the sulphur takes its place. For this purpose a reverberatory furnace is used, fitted with shallow pans lined with lead, into which the salt and acid are put, and over which the fire from the furnace passes. The pans are charged with equal weights of salt and sulphuric acid of specific gravity 1·45, which are well mixed up by means of a rake, and then the door is closed and the furnace heated. About an hour's roasting will suffice to convert the salt into the sulphate of soda, so that the same furnace will serve for several charges in the course of the day, turning out 9½ tons of the sulphate to every 8 tons of salt. During this process the hydrochloric acid has been driven off, but the manufacturer cannot allow it to escape into the atmosphere by the chimney, because, in the first place, it is of value, and, in the second, it would be a serious nuisance to all his neighbours; the gas, therefore, is made to pass through condensers—high chambers, packed with bricks and coke, through which a shower of water is continually falling; the water absorbs the gas as it rises from below, and forms aqueous hydrochloric acid. The furnace is often arranged with a lofty chamber or tower between it and the condenser, in which limestone is placed, for the purpose of absorbing a part of the chlorine, and producing chloride of lime, or bleaching powder. By these various means scarcely any of the chlorine is lost, and the profits of the soda manufacturer are considerably enhanced. This sulphate is known in the trade as *salt cake*.

The sulphate of soda has now to be converted into the carbonate. For this purpose it is roasted with about an equal quantity by weight of chalk or limestone, and one-half its weight of coal, in a reverberatory furnace. These substances are generally broken up small, and well mixed together, and as soon as the furnace is heated to a bright red heat the charge is gradually introduced into the first compartment of the furnace. As soon as it has been sufficiently heated through, it is transferred to the second, where it is subjected to a higher temperature, and forms a soft doughy mass, which is kept well worked by means of long iron stirrers. During this process the mass evolves carbonic acid, and as soon as the gas has all passed off, and the contents of the furnace assume a tranquil liquid condition, they are raked out of the furnace and allowed to cool. The substance which results from this treatment is commonly called *ball soda*.

It will be seen from this description that a considerable amount of manual labour is necessary at this stage of the process; and the success of the operation greatly depends upon the charge being well worked by the stirrers while it is in the furnace—very hot and laborious work. A very interesting arrangement is now adopted in most of the best alkali works, in order to avoid the stirring altogether. The furnace itself is made to rotate by means of a steam-engine, and as it turns the ingredients become thoroughly and uniformly mixed. The part which receives the charge consists of a long iron drum, turning horizontally upon its axis—the flue passing through the two axes—and having a door in the circumference, which serves both for charging and discharging it, according as it is brought to the uppermost or lowermost part of its circuit. The charge passes in through a hopper, the aperture is closed, and the furnace is made to revolve. When the roasting is complete, the door is opened, and the charge passes out into receivers placed below.

The *ball soda*, hand made, consists of porous lumps, of a dirty grey colour, composed principally of carbonate of sodium, sulphide and carbonate of calcium, and carbon. Revolver balls are much harder and more solid. Reduced to powder, it is sold, and exported in considerable quantities, under the name of *black ash*. The balls will fall to pieces of themselves by merely damping them with water and exposing them to a high temperature.

Carbonate of soda is very readily soluble in water at any temperature, though hot water will take up much more than cold. Advantage is taken of this circumstance in order to separate the carbonate of soda from the other ingredients contained in the ash. A series of cisterns, having false bottoms, are therefore filled with the *black ash*, and water is made to pass gradually through them in regular succession, taking up more and more of the soda as it passes along, until it is fully saturated, and the ash is quite exhausted. It is generally found convenient to keep the water at a temperature of something over 100° Fahrenheit.

Having thus obtained an aqueous solution, the water has to be evaporated, so as to separate the soda in a solid state. The evaporation of so large a bulk of water involves the expenditure of a great amount of heat, so that, as a matter of economy, the waste heat as it passes from the balling furnaces is ordinarily made to serve this purpose. Various forms of evaporating pans or troughs are used, and in some works the crystals as they form are raked out by manual labour, while in others machinery is adopted for this purpose. The soda thus obtained contains generally about 70 per cent. of carbonate, 15 per cent. of the hydrate, and 6 per cent. of the sulphate.

In order to free the carbonate from the other compounds, the ash is again heated in a reverberatory furnace, with a little sawdust or small coal. Care must be taken not to heat it so highly as to cause the ash to fuse, which would entirely defeat the object; and during the process the ash must be kept well stirred. By this means the sulphur is driven off, and at the same time the excess of carbon, after having converted both the sulphate and caustic soda into the carbonate. This, when ground to powder, is the ordinary *soda ash* of commerce. If *white alkali* be required, the soda, after coming out of the carbonating furnaces, is again dissolved by means of steam, and then allowed to crystallise out on cooling. In this state soda is used in various manufactures, such as in soap boiling and plate-glass making. For other purposes it must be still further treated.

To produce what are commonly known as *soda crystals*, the white alkali is again dissolved in boiling water, and then either filtered or transferred to iron tanks, where the liquor is left to settle for about twelve hours. If necessary, the latter operation is repeated a second time, and a little lime is added, to assist in throwing down the remaining impurities. It is boiled until it attains the specific gravity of 1·3, and then left to stand until the temperature falls to 92° Fahrenheit, when it is run out into large cooling pans to crystallise. Upon the surface of the liquor in these pans bars of wood are placed, which constitute a nucleus for the formation of the crystals. Attaching themselves in the first instance to the wood, they grow downwards into the liquor, forming beautiful masses of large pointed crystals. In the course of from five to ten days, according to the season of the year, the liquor is exhausted as far as is possible by this means, and being drawn off, it is evaporated down, so as to preserve the residue, which forms an inferior white alkali. The soda crystals are almost pure carbonate of sodium, with ten equivalents of water of crystallisation ($Na_2CO_3+10H_2O$); or, in round numbers, about 37 per cent. of carbonate of sodium and 63 per cent. of water. This is as pure as it can be made in such large quantities as are required in commerce, and accordingly the description of the manufacture of the carbonate of sodium stops at this point.

Caustic soda is also made now on a considerable scale at the chemical works, as there is an increasing demand for it on the part of bleachers and soap boilers. It is the hydrate ($NaHO$), and is made from waste liquors, or from the black ash, or soda ash, already described, by dissolving it in sufficient water to produce a liquor of a specific gravity of about 1·1, which is then put into a large vessel and stirred actively while lime-water is being gradually added to it. After about half an hour it is left at rest, the decomposition having been completed; and the lime, having taken up the carbonic acid of the soda, is gradually deposited in the condition of carbonate of lime at the bottom of the receiver. The soda liquors, being drawn off into boilers, are then concentrated, during the several stages of which process the sulphate, chloride, and other impurities crystallise out, and are removed by perforated ladles. The remaining liquor is finally boiled down until it is thoroughly concentrated, and is then left to cool, when it becomes solid. For some purposes the caustic soda is sold in the liquid state; and in this case the boiling is stopped when the solution has been raised to a specific gravity of about 1·35, at which strength it retains its liquid condition on cooling. This is commonly called *soaper's lye*.

Bicarbonate of soda, or the acid carbonate ($NaHCO_3$), may be prepared from the neutral carbonate already described, by filling a chamber with the soda crystals, and then passing carbonic acid gas through it. The gas may be generated by decomposing chalk or limestone (carbonate of lime) with

hydrochloric acid, the chlorine combining with the lime and freeing the carbonic acid. In the course of ten to fourteen days' exposure to the action of this gas, the soda crystals will have taken up a second equivalent of carbonic acid, and thus have become a bicarbonate. It will be seen, by a comparison of the chemical formulæ, that the relative proportion of the carbonic acid to the soda is double that given above for the carbonate of soda. The bicarbonate is then gently heated for the purpose of drying it, and ground to a fine powder. Care must be taken not to make it too hot, or the carbonic acid will be driven off again, and it will be reduced to a carbonate.

Soda-works must always be situated in places where salt, sulphur, limestone, and coal can be obtained on favourable terms, l also where there is plenty of waste land for depositing the refuse. The quantity of this is so great that large mounds of it are always to be seen in the neighbourhood of the works, and it would be greatly to the advantage of the trade if a means of utilising it could be found.

The pyrites, now so largely used, consist of the sulphurets of iron and copper, and the latter metal is frequently in sufficient quantity to be worth extracting. Copper-works are accordingly rising side by side with the soda-works, and are usually carried on in conjunction with the latter, no less than 7,600 tons of copper having been made in 1869 from the pyrites used in the manufacture of soda. This represents one-eighth of the whole quantity of copper smelted annually in this country, and furnishes one instance amongst many of how one industry reacts upon another.

PRACTICAL PERSPECTIVE.—II.

FIG. 7.—The object of this illustration is to show that *all lines which in Nature are at right angles to the plane of the picture must in the drawing converge to the centre of vision.*

But little argument will be required to convince the student of this. He will have noticed how the metals on a railway seem to meet in the distance, and how the two sides of the pavement of a long street converge: he can, in fact, scarcely cast his eye around without being impressed with this fact.

Fig. 8.—It will be clear then, that as a line which is at right angles to the plane of the picture is drawn to the centre of vision, any *point* which moves away from us, in a straight line from the foreground to the distance, will travel in such a line.

The student who has followed the course laid down in other lessons in this work, will have learnt how to construct scales of different proportions; but to others it will be necessary to explain, that as but few objects are drawn of their real size, a method is adopted by which their different parts, etc., shall be kept in a certain proportion to those of the object itself; this is called "drawing to a given scale."

Thus, if it is said that an object is drawn to the scale of "1 inch to the foot," it is meant that whatever is 1 *foot* long in the object is represented by 1 *inch* in the drawing, and thus the representation will be *one-twelfth* of the real size.

Now in Fig. 8 the scale adopted is $\frac{1}{8}$ of an inch to the foot.

The eye of the spectator is supposed to be 5 feet above the ground, and 11 feet distant from the picture. To represent this—

Draw the picture-line, P L, and the horizontal line, H L, at 5 feet (that is, $\frac{5}{8}$ of an inch) above it.

Place the centre of vision, C, anywhere (in this case) on the horizontal line.

The spectator is to be 11 feet distant; therefore set off 11 feet on each side of C, and the points of distance, P D, will be thus obtained.

Now let it be required to find the perspective position of a point which is 9 feet on the left side of the spectator, and 2 feet back; or as it is called, 2 feet *within* the picture.

Whenever a point in the distance is to be found, it is necessary, in the first instance, to ascertain its exact place in the foreground; thus, having drawn the perpendicular, C A, set off from A, 9 feet along the picture-line; then A′ is the position of the point at 9 feet on the left of the spectator; but as yet it is in the *foreground*, not back in the picture.

Now it will be clear, that as this point moves directly backward, it will travel in a line at right angles to the picture-line, and that such a line will vanish in the centre of vision.

Therefore, from A′ draw a line to C, which will be the perspective representation of a line running directly backward into the distance.

But it is required that the point in question shall be not only 9 feet on the left of the spectator, but 2 feet *within the picture.*

To find its position, then, set off 2 feet on the right of A′—viz., point 2; and from 2 draw a line to the point of distance, P D.

Then 2′ will be the required position of the point—viz., 9 feet on the left of the spectator, and 2 feet within the picture.

Now let it be required to find the perspective position of a point which is 9 feet on the left of the spectator, and *four* feet within the picture.

This is simply the same point, which is supposed to have travelled 2 feet farther back; therefore, from A′ set off point 4 (that is, *two* feet added to the former 2), and draw a line from 4 to the point of distance; then 4′ will be the perspective position of the point.

Proceed in the same manner to find the position of the same point when it has travelled 6 and 8 feet backward, and thus obtain points 6′ and 8′.

Fig. 9.—Now let it be required to find the position and apparent height of a perpendicular, the *real* height of which is 12 feet, when it stands at 9 feet on the right of the spectator, and 2 feet within the picture.

At B, 9 feet on the right of A, draw a perpendicular, B D, 12 feet high by scale; and from the top and bottom of it draw lines to the centre of vision. This would represent a *wall* or *plane* extending from the foreground into the distance.

Now it is clear that the required perpendicular will be somewhere in this plane; the question is, *where?*

This is solved by the application of the last study. Set off from B 2 feet along the picture-line—viz., point 2; from 2 draw a line to the point of distance, and this line, cutting B C in 2′, will give the position of the line.

At 2′ draw a perpendicular meeting the line D C, and this will be the line required—which, it will be observed, has diminished, because it is a little distance back in the picture.

Proceed in the same manner to find the position of the same perpendicular when it is at 4, 6, and 8 feet within the picture.

EXERCISE 1

The height of the spectator is 6 feet, the scale being $\frac{1}{4}$ of an inch to the foot; the distance of the eye is 13 feet.

Find the positions of the following points:—

(1.) 11 feet on the right of the spectator, and 3 feet within the picture.
(2.) 8 feet on the right of the spectator, and 6 feet within the picture.
(3.) 10 feet on the left of the spectator, and 7 feet within the picture.
(4.) 3 feet on the left of the spectator, and 12 feet within the picture.

EXERCISE 2.

The spectator is 5 feet high, and 15 feet distant from the picture.

Find the position and perspective heights of the following perpendiculars:—

(1.) 8 feet on the left of the spectator, 10 feet high, and 3 feet within the picture.
(2.) 12 feet on the left of the spectator, 11 feet high, and 6 feet within the picture.
(3.) 13 feet on the right of the spectator, 12 feet high, and 10 feet within the picture.
(4.) 11 feet on the right of the spectator, 4 feet high, and 8 feet within the picture.

Now this study will show the method of solving a question which has often been given in examinations—namely, that of finding the position of a bird flying at a certain distance from the spectator, and at a given height.

Let us suppose the measurements to be these:—Distance on right of spectator, 9 feet; height from ground, 12 feet; distance back in the picture, 20 feet.

Now it will be clear to the student that if a bird flying held in its talons a line with a weight at its end, such line would be a true perpendicular to the ground, the bird being at its upper extremity, and thus the whole question resolves itself into this: Put into perspective a perpendicular 9 feet on the right of the spectator, 12 feet high, and 2 feet within the picture.

To do this we simply return to Fig. 9.

Here we have already drawn a perpendicular, B D, at 9 feet on

the right of the spectator, and 12 feet high, and we have drawn lines from its extremities to C.

It now only remains to set off 20 feet along the picture-line from B, namely, B 20, and from 20 draw a line to the point of distance. This will give the point *b*, which is the position of the perpendicular to be drawn on *b* to meet D C in *c*.

Then *c* is the position of the bird, as required.

Fig. 10.—It is not necessary in every case to show both the points of distance; thus, as in this study—a line on the right side of the spectator—we can dispense with the left-hand point of distance. Here the height of the eye of the spectator is 6 feet ($\frac{1}{8}$ scale), and his distance 16 feet.

The subject of this study is a line which lies at right angles to the plane of the picture, at 12 feet on the right of the spectator, and 4 feet back in the picture, the length of the line itself being 6 feet.

From A, the point immediately under the centre of vision, set off 12 feet, namely, to B, and draw a line to C.

From B, towards A, set off 4 feet, namely, to C′, and draw a line to the point of distance. This will give the point *c*.

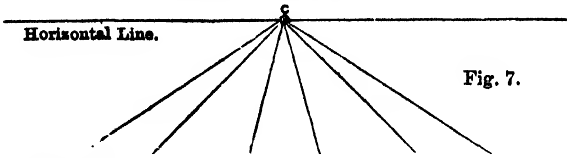


Fig. 7.

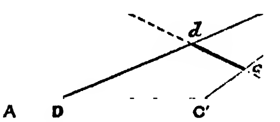


Fig. 10.

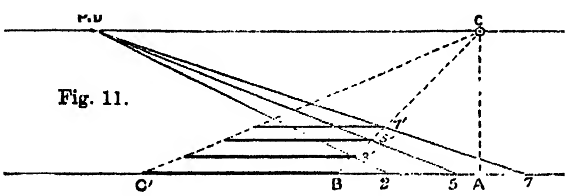


Fig. 11.

From C′ set off 6 feet on the picture-line, namely, to D, and draw a line from D to the point of distance, cutting B C in *d*.

Join *c d*, and this will represent the line in the perspective position required.

EXERCISE 3.

The height of the spectator is 5 feet, and his distance 15 feet (scale, $\frac{1}{4}$ inch to the foot).

Give the perspective projections of the following lines, lying at right angles to the picture-plane :—

(1.) 7 feet long, at 10 feet on the left of the spectator, and 2 feet within the picture.

(2.) 9 feet long, 6 feet on the left of the spectator, and 4 feet within the picture.

of the spectator, and 6

(4.) 8 feet long, 6 feet on the right of the spectator, and 2 feet within the picture.

Fig. 11.—The scale in this study is $\frac{1}{8}$ of an inch to the foot. The height of the spectator is 6 feet, the distance 16 feet.

Here a line, B C′, 8 feet long, lies in the immediate foreground, the end B being 6 feet on the left of the spectator.

It is required to put this line into perspective when lying at 2, 5, and 7 feet within the picture.

From B and C′ draw lines to the centre of vision, and as the line B C′ is to travel backward, but remain parallel to the picture-line, it must, however it may change position, be contained between these two lines. Now from B mark off B 2, B 5, and B 7, representing the distances at which the line is to be placed. From each of these points draw lines to the point of distance, cutting B C in 2′, 5′, and 7′.

From these points draw lines parallel to C′ B, and contained between B C and C′ C. These will be the perspective representations of the line C′ B at the distances of 2, 5, and 7 feet within the picture.

EXERCISE 4.

Scale $\frac{1}{4}$ inch to the foot. Height of the spectator, 6 feet; and his distance, 15 feet.

Put into perspective a line 6 feet long, when lying parallel to the picture-plane, at the following distances :—

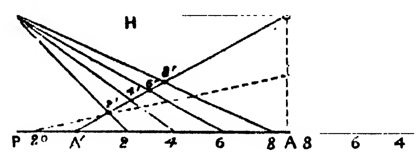
(1.) When one end is at 3 feet on the left of the spectator, and the line is 4 feet within the picture.

(2.) When one end is at 4 feet on the right of the spectator, and the line is at 10 feet back.

Fig. 12 shows three squares, (1), (2), (3), lying flat on the ground, their front and back lines being parallel to the plane of the picture, and their sides at right angles to it.

Fig. 9.

Fig. 8.



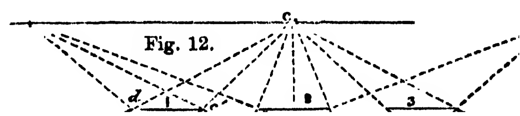


Fig. 12.

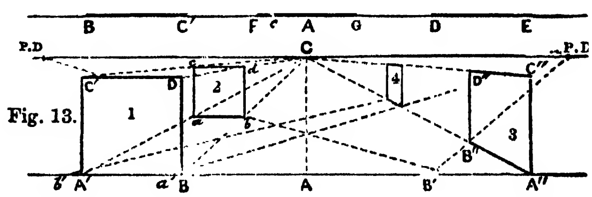


Fig. 13.

Here the eye of the spectator is 5 feet above the ground (or picture) line, and the distance is 11 feet ($\frac{1}{8}$ scale).

The sides of the squares are 4 feet, C′ and D are 5 feet on the left and right of the spectator, whilst F G is immediately in front.

Having drawn lines from B, C′; F, G; and D, E to the centre of vision, between which the squares must be contained, the next question is how to find the place for the back line of each.

The general method of finding the position of a horizontal line at any given distance has been shown in the last figure, and this could be applied in the present study—namely, by setting off from C′ the distance *c*, equal to the length of the required side of the square, and drawing from *c* a line to the point of distance. This would be the method to be pursued for any rectangle; but for a square an easier method can be found, by which the trouble of marking the point *c* can be saved—namely, by drawing a line from C′ to the point of distance, which, by cutting B C in *d*, will give a point immediately opposite to *c*′, and a horizontal line drawn from this point will complete the figure.

This is again shown in Fig. 12 (2), (3). It is not really necessary in (2) to draw a line to each of the points of distance, but in early studies it is best to do so as an additional test of accuracy.

EXERCISE 5.

Scale $\frac{1}{4}$ inch to the foot. Height of spectator, 6 feet; and distance of spectator, 16 feet.

Put into perspective three squares lying flat on the ground with their front and distant edges parallel to the plane of the picture.

(1.) 3 feet side, immediately in front of the spectator and in the foreground.

(2.) 4 feet side, at 5 feet on the left of the spectator, and 8 feet within the picture.

(3.) 2' 6" (2 feet 6 inches) side when lying at 6 feet on the right of the spectator, and 9 feet within the picture.

For Fig. 13, the height and distance of the spectator are the same as in the last figure (Fig. 12).

Fig. 13 (1) is a square of 4 feet side, standing on one of its edges, its surface being parallel to the picture-plane, and its nearest angle, B, being 5 feet on the left of the spectator.

As there will be no difficulty in constructing this original square, A' B D C', we can therefore at once proceed to find its position and size when removed 11 feet within the picture.

From A' and B draw lines to the centre of vision. From B set off on the picture-line the length B' (11 feet), and from that point draw a line to the point of distance, cutting B C in b.

At b draw the horizontal line b a, which will be the base of the square at the required distance. Now, knowing the figure to be a square parallel to the plane of the picture, we could easily complete this study by constructing a square on a b, as in Fig. 13 (2). But this method would apply to a square only, and if any other parallelogram were required, we should have to obtain the size by the following process :—

At a and b erect perpendiculars of *any* height (temporarily). Draw lines from the upper angles C' and D of the square or other parallelogram to the centre of the picture; then these, cutting the distant perpendiculars, will give the points c, d; and these joined will complete the square at the required distance.

EXERCISE 6.

Scale, ½ inch to the foot; height of spectator, 6 feet; distance 18 feet.

Put into perspective a square of 9 feet side, when standing with its surface parallel to the picture-plane.

(1.) When in the foreground, at 7 feet on the left of the spectator.

(2.) When at 5 feet on the left of the spectator, and 10 feet within the picture.

Fig. 13 (3).—In this study the square is rotated on the line A" C," so that its surface is at right angles to the picture-plane.

Having erected the perpendicular A" C", at (say) 9 feet on the right of the spectator, draw lines from its extremes to the centre of vision. From A" mark off on the picture-line the length A" B' equal to the side of the square; and from B' draw a line to the point of distance. This, cutting the line A" C in B", will give the point for the distant edge B" D" of the square.

Fig. 13 (4) is the same figure removed to 15 feet within the picture. As the working is shown, and as the method is similar to what has already been done, it is hoped that the student will be able to obtain the required result without further instructions.

EXERCISE 7.

Scale ½ inch to the foot; height of spectator, 5 feet; distance, 15 feet.

Put into perspective the squares, the dimensions of which are given below, when standing at the stated distances; the plane (or surface) of the square *to be in every case at right angles to the picture-plane.*

(1.) 3 feet side, at 2 feet on the left of the spectator.

(2.) 8 feet side, at 7 feet on the left of the spectator, and 6 feet within the picture.

(3.) 4 feet side, at 3 feet on the right of the spectator, and 2 feet within the picture.

(4.) 7 feet side, at 9 feet on the right of the spectator, and 6 feet within the picture.

WEAPONS OF WAR.—VI.

BY AN OFFICER OF THE ROYAL ARTILLERY.

BREECH-LOADING SMALL ARMS (*continued*).

IN a former paper we have treated of the transition from muzzle-loading to breech-loading rifles for military use, and have shown how this was accomplished in our own service, by the simple and satisfactory expedient of fitting the Enfield rifle with an arrangement which admitted of its being loaded at the breech, and providing it with a suitable and ingenious breech-loading cartridge. The combination gave us an arm about equal to the old Enfield rifle in shooting power, but more destructive, in consequence of the employment of a hollow bullet, and capable of greatly increased rapidity of fire. But it was clear that we had not here the final and complete solution of the question. The shooting power of the old Enfield was not of a sufficiently high character to satisfy the requirements of the present age. Since 1853, when this weapon was introduced, vast strides have been made in arms of precision; and the Enfield rifle is now unable to hold its own against the small-bore rifles which surpass it in accuracy, range, flatness of trajectory, penetrative power, and other valuable qualities. So also with regard to the breech action: many minds have been at work on this question for several years, and the result is that there exist several breech mechanisms which are as superior to the Snider as the small-bore rifle is superior to the large bore.

Therefore, it became a recognised necessity for the military authorities to look beyond their converted Snider-Enfields to a new arm for future manufacture. It would occupy too much space if we were to attempt to describe the steps and experiments which have finally resulted in the adoption of a composite arm—the Martini-Henry rifle. This arm has the form of barrel designed by Mr. Alexander Henry, of Edinburgh—viz., a polygonal barrel, the angles of which are broken by ribs which create re-entering angles, the inscribing circle tangential to the ribs being described with the same radius as the inscribing circle tangential to the plane sides. The twist of rifling is 1 turn in 22 inches. The calibre is ·45 inch. Admirable results have been obtained with these barrels, which are now very generally adopted by military rifle-makers, who fit on to them different breech-actions, according to their fancy. The initial velocity of the rifle, with a charge of 85 grains, is about 1,365 feet per second, against 1,250 for the Snider; this, taken in conjunction with the fact that the bullets are of the same weight (480 grains), but that the Henry bullet is of less diameter than that of the Snider, results in a considerably flatter trajectory on the part of the Henry bullet, in greater range and in greater accuracy. Also, the Henry bullet is less affected by wind.

What breech-action should be fitted to this barrel to render it a perfect arm? This question has given rise to immense discussion and to innumerable experiments. Mr. Henry himself had a breech-action of great merit, which some persons thought it would be well to employ. But the question was directed to be settled experimentally, and the result of the experiments was that the Henry breech mechanism had to yield the palm to a mechanism designed by Mr. Martini, a naturalised Swiss subject. This action is best described by the drawings given in page 336.

The action consists, as will be observed, of a falling block, hinged upon a pin which passes through its rear end, the recoil being taken by the iron framework at the back. Inside this block is situated the striker, by means of which the cartridge is exploded, and the strong spiral spring by means of which the striker is actuated. The block is raised and lowered by a lever, which in the act of lowering the block also compresses the spring, thereby bringing the rifle to full cock; and the front end of the block striking smartly upon the bent lever, the extractor ejects the empty cartridge. When the fresh cartridge has been introduced, the block is returned to its place by the return movement of the lever, and the arm is ready for firing; or, if it be not desired to fire it immediately, there is a small safety-bolt, easily manipulated by the fore-finger and thumb, which serves to lock the arm and prevent it from going off. Also, the gun is provided with an "indicator" at the side, to show when it is cocked. The indicator, being attached to the "tumbler," moves with it and parallel to it; and as the arm cannot be cooked unless the tumbler be in a certain position, the indicator shows infallibly its condition.

The tests which the Martini-Henry breech-action has undergone have been extraordinarily severe, although scarcely more so than the criticism to which it has been subjected. This criticism has, however, had this good effect: if it has somewhat interfered with the early adoption of this arm, by rendering necessary continued trials, it has, through these trials, fully established the extraordinary merits of the breech-action. At first the objection was urged that, although one or two show specimens, prepared specially for trial, might succeed in satisfying such tests as the Committee were able to impose, the arms, if placed in the hands of the troops, would certainly break down. To meet this, 200 Martini-Henry rifles were issued to the troops, who for about a year and a half had them under

trial. The result of these trials, carried on in all climates, from India to Canada, in all weathers, and under all sorts of circumstances, elicited most favourable reports of the arm. Then it was urged by others that at any rate the arrangements of the breech were mechanically defective; that no mechanical engineer could have any doubt on this point; that a mechanism radically unmechanical could not continue to give reliable and satisfactory results. Accordingly, the evidence was taken of three very eminent mechanical engineers—Professor Pole, Mr. Nasmyth, and Mr. Woods. These gentlemen, instead of pronouncing a condemnation of the mechanism, declared that it was an excellent piece of work, and passed high encomiums on its simplicity, strength, and efficiency. The criticism that as the recoil is taken by the breech axis pin, that pin must necessarily wear away or break in time, they met by the statement that the recoil is not taken by the pin at all, but by the socket behind the block, whence it is transmitted throughout the whole system of the rifle, the weight of which is thus brought to resist it; and this statement they supported by reference to a very simple experiment, in which the block axis pin had been replaced by one of lead, on which no mark of any recoil was perceptible. In another instance the gun was worked perfectly without any pin at all. The spiral spring was a prominent point of attack. It constituted, so to say, the citadel of the system, and against it all the main efforts of the opponents of the arm were strenuously directed. One inventor of a rival breech-action based his claim mainly on the substitution in his system of a flat for a spiral spring. This objection the mechanical engineers met very decidedly. For the purpose for which it was required in this gun—viz., to cause a striker to impinge directly upon the percussion-cap of a breech-loading cartridge—they greatly preferred the spiral to the flat spring. It was cheaper—as a halfpenny to sixteen-pence—it admitted of a more compact arrangement of parts; it was, notwithstanding all that had been said to the contrary, quite as reliable as a flat spring—a point which they supported by quoting various well-known applications of spiral springs; it was as easy to make of uniform quality in large quantities; and as for the statement that the spiral spring gave more of a push than a blow, one witness showed mathematically that the blow which was struck by the spiral spring in the Martini-Henry was really a quicker, smarter blow than that struck by the hammer of the Snider. As to the merits generally of the spiral spring—the point which inventors of other systems declared to be fatal to the Martini—all the mechanical witnesses agreed in pronouncing it thoroughly mechanical, sound, and reliable. Then it was objected that the divided stock was weaker than the ordinary gun-stock. Not so, said the engineers; it was rather stronger; and if desired it could be made stronger still. Nor is this mere theory. They appealed to the results of an experiment which was carried out at Enfield in their presence to test this point. And so, before the independent testimony of thoroughly competent, indeed, distinguished witnesses, the criticisms which were very freely indulged in by those who had rifles of their own which they would prefer to see introduced, melted away. Whether criticism will therefore cease it is not easy to say; probably it will not. But the readers of these papers at any rate will have the assurance that the future arm of the British soldier, whatever may be said about it, has undergone tests and trials to which no other weapon was ever submitted; that it has passed one ordeal after another not merely satisfactorily, but triumphantly—the ordeal of the rigorous trials which were instituted by Lieut.-Colonel Fletcher's Committee; the ordeal of knocking about and handling by the troops; the ordeal of public trials at Wimbledon, where the arm has carried off very many of the more important breech-loading prizes; the ordeal of public criticism; finally, the ordeal of a minute scrutiny at the hands of professional mechanics. If an arm can stand all this, and come out unscathed, as the Martini-Henry has done, it is surely a fit arm to put into the hands of our troops. This, then, is the selected weapon of the British soldier—the Martini breech allied to the Henry barrel.

The cartridge to be used with this arm is the Boxer, but of a form different from that in use with the Snider. The first cartridges made for the Martini were very long, the small diameter of the barrel and the large charge of powder rendering necessary this length, so long as the cylindrical form of cartridge was retained. To this cartridge objections were made on account of its length. Accordingly the form was modified, the substantial features of the Boxer construction being retained. In the modified cartridge the body is enlarged in diameter, and tapered down at the fore-part to the diameter of the bullet. The outline of the cartridge is thus that of a long-necked bottle, whence the name by which it is frequently known, the "bottle-neck" cartridge. A drawing of this "short-chamber" cartridge, as it is officially designated, shows the details of the construction, and it will be observed, on a comparison of this drawing with that given in a former paper (page 272) of the Boxer cartridge for the Snider, that the construction of the two cartridges is practically the same. There is the thin coil-case, the iron disc base, the strengthening cup, the papier-mâché wad by which the parts are held together, the cap and anvil arrangement for ignition.

But the fore-part of the cartridge is different; the mode of lubricating is different; the bullet (which is Mr. Henry's) is different; the cartridge is not covered with paper; and the base is strengthened by means of the insertion of a piece of tin between the folds of the brass, thereby obviating the necessity for additional strengthening cups. A few words may be said with regard to the bullet and lubrication. The bullet is solid, with the exception of a shallow cavity in the base, into which the folds of the paper which envelops the bullet are inserted. At its back end, the bullet is of the same diameter as the bore, viz., ·45 inches. It tapers slightly, until at the shoulder the diameter is only ·439 inches. In a former paper it has been explained that the main feature of the bullet for the original muzzle-loading Minié and Enfield rifles consisted in the arrangement by which the bullet was expanded into the rifling, by the explosion of the charge acting upon an iron cup, or a wooden plug in a hollow at the base. Thus the bullet entered the rifle fitting loosely, and left it fitting tightly. In a breech-loader, however, there is no necessity for having a bullet which will enter the barrel easily, as it is generally introduced into a chamber at the breech end, and may be made in the first instance of the full requisite diameter. We have seen, however, that Colonel Boxer in his bullet for the Snider did retain the plug expansion, with a view partly to getting the requisite length of bullet in a large-bore rifle without any undue increase of weight. But in the Henry rifle no such device is necessary, and Mr. Henry therefore made his bullet of the full diameter of ·45 inch, depending upon such slight enlargement as the bullet received by the opposition of its own inertia to the shock of discharge, to take up the rifling. The action of Mr. Henry's bullet therefore depends upon what is known as the "overtaking" principle, the back end of the bullet slightly overtaking the fore end, owing to the inertia of the mass in front, and thereby setting up, and expanding the bullet into the grooves.

The lubrication of this rifle is effected by means of a cylindrical wad of pure bees'-wax, placed behind the bullet, and enclosed in discs of jute cardboard, to prevent it from striking either to the bullet or to the powder. This wad was originally made solid, but it was found not to act perfectly in very cold weather, and it was therefore thickened and hollowed out in front, thus giving more space for the powder to act through, and less work for it to do. The wad is squeezed between the exploded powder charge and the bullet, and just as the bullet is set up and enlarged, so the wax wad is set up and enlarged, although of course to a far greater extent, and as it is driven through the bore, lubricating it effectually.

It remains now only for us to say a few words with regard to the powers of the Martini-Henry rifle, using the ammunition above described. The accuracy of shooting of the arm is remarkably great. The following facts extracted from official records are satisfactory upon this point. At 300 yards, the mean radial deviation of 20 shots fired from a fixed rest, has been as good as ·47 feet; at 500 yards, ·79 feet; at 800 yards, 1·29 feet; at 1,000 yards, 2·19 feet; at 1,200 yards, 2·28 feet. Perhaps these figures will scarcely convey to all our readers the impression which they would make upon the mind of any one who is familiar with the mode of estimating "figures of merit" in rifle-shooting, namely, to find out by calculation the centre of each group of 20 shots, and to find the mean distances of these shots from this centre. Obviously, the smaller this distance, the smaller the limits of the group, and the more ac-

curate the shooting. When a trial was made between the Snider, the Chassepot, and the Martini-Henry, the following results were obtained:—

	Martini-Henry.	Snider.	Chassepot.
500 yds.	·815 feet.	1·47 feet.	2·77 feet.
800 „	1·57 „	3·78 „	5·22 „
1,000 „	3·66 „	8·34 „	13·08 „

Putting this into a popular form of expression, it means that, if we take the Martini-Henry as a standard, as equal to 100, we have the following comparison—

		At 500 yds.	At 800 yds.	At 1,000 yds.
Snider	=	55·4	41·5	43·9.
Chassepot	=	29·4	30·0	28·0.

Or, expressing it more roughly still, we have the following tabular comparison of the performances of the rifles, namely:—

	At 500 yds.	At 800 yds.	At 1,000 yds.
Martini-Henry to Snider, as about	2 to 1	2½ to 1	2½ to 1.
Chassepot, „ „ „	3 to 1	3 to 1	3 to 1.

Let us now turn to the trajectory of the arm. It is obvious

It will be observed that the Chassepot bullet has a slightly higher initial velocity than the Martini-Henry, but the bullet being lighter (380 against 480 grains) it has less power to overcome the resistance of the air, and therefore soon loses this high velocity. At 150 yards from the muzzle, or even at a less distance, the Martini-Henry bullet will be travelling with a velocity equal to that of the Chassepot, and from that point forward the latter will gradually be losing in the race.

The effect of this high velocity, combined with a good weight and a small diameter, is to give the Martini-Henry bullet great penetrative power, as well as that low trajectory which has been spoken of. It has been found by experiment that the bullet will penetrate as follows:—14½ half-inch elm planks at 100 yards; 3 three-inch fir balks dry, in addition to 1 wet, at the same distance; 1 plate of ·261 inch iron at 200 yards; 4 thicknesses of 3-inch rope at 350 yards; a gabion filled with clay earth at 25 yards; a sap roller at 25 yards; a sand-bag at 100 yards.

While the normal accuracy of the Martini-Henry rifle is far


Fig. 7.

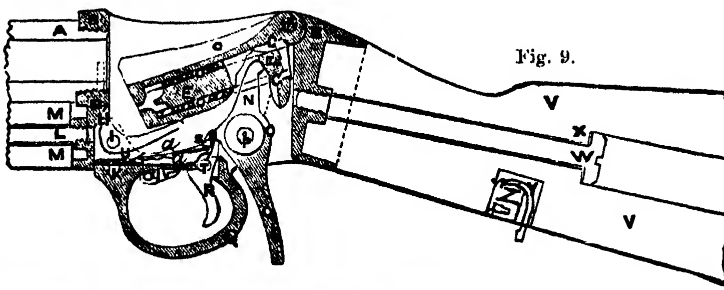


Fig. 9.

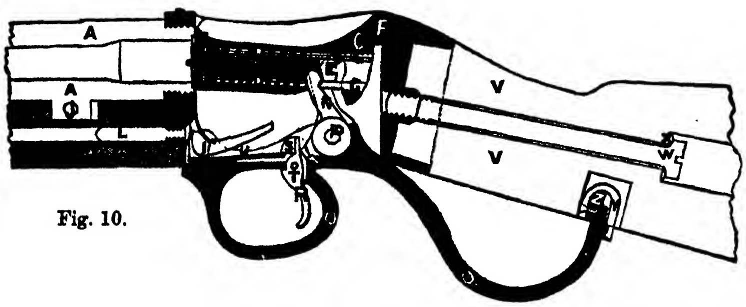


Fig. 10.

Fig. 8.

Fig. 7. BOXER-HENRY CARTRIDGE, ELEVATION. Fig. 8. BOXER-HENRY CARTRIDGE, SECTION. Fig. 9. SECTION OF BREECH OF MARTINI-HENRY RIFLE, OPEN. Fig. 10. SECTION OF BREECH OF MARTINI-HENRY RIFLE, CLOSED.

Refs. to Letters in Figs.—Fig. 9, 10:—A, barrel; B, body of breech-action; C, block; D, main-spring; E, striker; F, block axis pin; G, stop nut; H, extractor; I, extractor axis pin; J, pin for barrel stud-hole; K, trigger and rest spring screw; L, cleaning rod; M, fore-part of stock; N, tumbler; O, lever; P, lever and tumbler axis pin; Q, trigger-plate and guard; R, trigger; S, tumbler rest; T, trigger axis pin; U, trigger and rest spring; V, hind part of stock; W, stock-bolt; X, stock-bolt washer; Y, lever catch-spring; Z, lever catch-block and pin; *a*, locking bolt; *b*, locking bolt thumb-piece; *c*, thumb-piece screw; *d*, locking bolt-spring.

that the flatter an arm shoots—in other words, the lower its trajectory is—the more ground will the bullet cover in its flight. The greatest height of the trajectory of the Snider is 11·9 feet in 500 yards; of the Martini-Henry only 8·9 feet. The practical effect of this is that, supposing two men to be firing, lying on the ground, and aiming at the feet of a body of troops 500 yards distant, a body of infantry might safely cross the Snider range anywhere between 92 and 438 yards, the bullets flying over their heads, while in only from 139 to 396 yards would they be safe in the Martini-Henry range; and as for cavalry, while on the Snider range from 138 up to 400 yards they would be safe, there would on the Martini-Henry range be no spot which a cavalry soldier could pass in safety. Beyond 500 yards the advantage of the Martini-Henry rifle in respect of trajectory would be increasingly greater.

The next point is initial velocity—the velocity, that is to say, at which the bullet leaves the muzzle. This is as follows:—

Martini-Henry.	1,365	feet per second.
Chassepot	1,391	„
Snider	1,262	„

greater than that of the Chassepot and Snider, and enormously superior to that of the needle-gun, which is by far the worst arm of the four, the Martini-Henry bullet is less affected by wind—a great advantage to the marksman. The cartridge is stronger and better than that of the Chassepot. The rapidity of fire is more than double: thus, at an official trial—

The Chassepot fired 20 rounds in 1 minute 42 seconds.
The Martini-Henry „ 0 „ 48 „

Thus in seven points—namely, (1) increased strength and safety of ammunition, (2) greater accuracy, (3) longer range, (4) flatter trajectory, (5) higher penetrative power, (6) greater safety, strength and simplicity of construction, (7) increased rapidity of fire—the Martini-Henry is much superior to the Chassepot.

The improved Martini-Henry has a bore of ·40, is six ounces heavier, and is sighted to 2,000 yards with an attachable pendent front-sight. Its bullet weighs 380 grains, its rifling makes a complete turn in 15 inches, its trajectory at 500 yards is 6 feet, and its velocity is 1,600 feet a second. Thus it is a more effective weapon, and, with lighter bullets, more ammunition can be carried.

VEGETABLE COMMERCIAL PRODUCTS.—XI.

TEXTILE PLANTS, OR PLANTS FROM WHICH WE DERIVE CLOTHING AND CORDAGE (*continued*).

THE value of cotton in commerce depends on the length and strength of the silk or staple. Cottons may be divided into the long silk and short silk. The United States generally furnish the short silks in the greatest quantity, with the exception of one sort, known as the Georgia long silk, or Sea-island cotton, of which the production elsewhere is very limited. Cotton-threads are numbered from 1 to 300, according to the degree of fineness to which they are spun. In weaving, the cross threads or woof are shot by the machine across or at right angles to threads extending longitudinally, called the warp. Long silk cotton is generally spun into the threads for the warp, and the short silk is used for the woof.

The chief seats of the cotton manufacture in the United Kingdom are Manchester, Bury, Oldham, and Glasgow. Most of the many thousands of cotton-mills give employment to from 50 to even 1,500 hands, presenting the most perfect order in every department. All these persons are employed by means of the fine white silky hairs with which the Creator has clothed the seed of the cotton plant, in order to effect its dispersion, and which the ingenuity and skill of man now manufactures into clothing for many millions of the human race.

JUTE, or GUNNY FIBRE, is the produce of *Corchorus capsularis*, L. (natural order, *Tiliaceæ*), an annual, growing from twelve to fourteen feet high.

The fibre which is contained in the bark is generally about eight feet in length, and is obtained by treatment very similar to that adopted with the flax and hemp plants. Jute fibre is fine, and has a remarkable satiny lustre, so that it is sometimes mixed with the silk in the fabrication of cheap satins, and is very difficult to detect in the goods. Its chief use, however, is for making coarse canvas, or *gunny*, as it is called in India. Rice, oil-seeds, dye-stuffs, cotton, and sugar, are all sent to us from India in gunny bags or bales. When wet, jute fibre quickly rots, so that it is not adapted for the manufacture of either sail-cloth or cordage; but notwithstanding this, it is often mixed with hemp for the latter. The quantity imported in 1886 was 5,349,109 cwt.

NEW ZEALAND FLAX (*Phormium tenax*, Forst.; natural order, *Liliaceæ*).—A coarse growing plant, with long narrow leaves, the slender fibres of which glisten like silk, and are white as snow. Its flowers are of a brownish-red colour, and not at all ornamental.

This plant inhabits the marshes of New Zealand, but grows well in any soil; and in mild climates, such as the south of France, winters in the open air. It affords a fibre of great strength, stronger than hemp, which is extracted by maceration, drying, and heckling, as in the case of the other products. Good ropes can be made from the coarser, and very fine linen from the finer fibres. The quantities imported are at present inconsiderable, owing to the circumstance that the strength of the fibre is injured by maceration. No machinery has yet been contrived which can approach or even imitate the dexterity of the native women in separating the fibre from the coarser parts. New Zealand flax fibre will not bear a cross strain, and therefore cannot be tied into a knot without breaking.

COIR-FIBRE (*Cocos nucifera*, L.; natural order, *Palmaceæ*).—This fibre is obtained from the outer husk of the cocoa-nut. It is stronger than hemp, and more capable of withstanding the action of water. It is separated from the husk by beating, and then cleaned by heckling in the usual manner. The coir-fibre thus procured is spun by the natives of India and Ceylon into yarns of different length and thickness, which are largely exported to Europe. The yarn on reaching this country is manufactured into ropes, door-mats, and floor-mattings, which are far more durable than those made from bristles. In India, coir-fibre is very generally used for ship-cordage and fishing-nets. The annual importation into London and Liverpool comes chiefly from Ceylon and Bombay.

CARLUDOVICA PALMATA, L. and P. (natural order, *Pandaneæ*).—This species of screw pine is terrestrial, and bears fan-shaped glabrous leaves from six to fourteen feet long, and four feet in breadth. It ranges from 10° N. to 2° S. latitude on the American continent.

Panamá hats, which are distinguished from all others by consisting of a single piece, as well as by their durability and flexibility, are so named because they are shipped through Panamá, though a large proportion are manufactured in Guayaquil, Ecuador. The finest hats are made in South America with fibre of the unexpanded leaf, called "torquilla," from which are also made very fine hammocks.

The leaves are gathered before they unfold, all the ribs and coarser veins are removed, and the rest, without being separated from the base of the leaf, is reduced to shreds. After having been exposed to the sun for a day, and tied into a knot, the straw is immersed into boiling water until it becomes white; it is then hung up in a shady place, and subsequently bleached for two or three days. The straw (*paja*) is now ready for use, and in this state is sent to different places, where the Indians manufacture from it hats, hammocks, and those beautiful cigar-cases which cost as much as five and six pounds a-piece. The plaiting of the hat is done on a block, which is placed upon the knees; it is commenced at the crown and finished at the brim. According to the quality of the hats, more or less time is occupied in their completion: the coarser ones may be finished in two or three days, while the finest take as many months.

LEAF OF THE CASTOR-OIL TREE.

The average export from Guayaquil has been in the past six years from 15,000 to 16,000 dozens annually, the price varying from 2 to 130 dollars, according to fineness. Lately the leaves or raw material have been in demand for export, the average quantity shipped being about 200 to 250 cwt. annually.

These hats are also made in Veragua, Western Panamá, Costa Rica, and New Granada. The petioles of the leaf are made into baskets, called *petacas*, the fibre being variously dyed.

MANILA HEMP (*Musa textilis*, Tournef.; natural order, *Musaceæ*) produces a woody fibre, which is used in India in the manufacture of fine muslins; the most exquisite textile fabrics and the elegant manila hats are manufactured from it.

II.—OLEAGINOUS PLANTS, OR PLANTS YIELDING VALUABLE OILS.

Oil is of the greatest importance in the arts. It is extensively used for burning in lamps, for diminishing friction in machinery, for making candles and soaps, in the manufacture of paints and varnishes, and in wool-dressing—five gallons of olive, rapeseed, or other oils being used in the preparation of every pack of wool—also as an article of food, and as medicine. Oils are distinguished into two kinds: fixed or fat oils—which are obtained by pressure from the fruits or seeds of plants—and essential oils. The fixed oils burn with a clear white light, and boil at a high temperature, about 600° F.; most are liquid at the ordinary temperature, but cocoa-nut and palm oils are solid at 50° or 60° F. All the fixed oils are nearly inodorous, and lighter than water. The volatile or essential oils give off vapour at the temperature of boiling water when mixed with water, or under 320° F. by themselves.

The following are a few of the most important plants which yield the oils of commerce:—

(a) FIXED OILS.

PALM OIL is principally produced from the fruit of *Elais guineensis*, L., a native of the western coast of Africa. The fruit is about the size of an olive, of a yellow colour, three-fourths of which consist of a yellow oily pulp. This fruit is crushed and the oil extracted from the albumen by boiling in water. Palm oil is used in England principally in the manufacture of yellow soap, but with the Africans it is an article of food. A generation ago large tracts of country on the western coast of Africa were covered by the oil palm, then little cared for; now a large foreign demand for palm oil has sprung up, and with it property in these trees; and this oil trade has stopped the slave trade on the Gold coast, where it once flourished, and at the mouth of the Niger. The quantity of palm oil imported into the United Kingdom in 1886 was 1,004,419 cwt., valued at £1,050,459. The application of this oil to its industrial purposes gives employment to many thousands of people. Industry and a desire of accumulating property are at last manifest amongst the African population, and everywhere are now to be seen on this coast the germs of a nascent civilisation.

COCOA-NUT OIL is obtained from the albumen of the kernels of the cocoa-nut (*Cocos nucifera*, L.); it is principally used for making cocoa-stearine for candles. In Trinidad and Demerara it is used by the coolie labourers as we employ butter. The imports in 1886 were 156,775 cwt., almost the whole of which came from the British East Indies.

CASTOR-OIL PLANT (*Ricinus communis*, L.; natural order, *Euphorbiaceæ*).—This plant, in temperate climates, is a large herbaceous annual, with palmate peltate leaves, and monœcious flowers in terminal panicles, the lower male, the upper female. The capsules are prickly, globose, three-celled, with one seed in each cell. The seeds are ovate, shining, of a grey colour, marbled with black. The form of the leaf is shown in the preceding page.

The castor-oil plant is a native of India, Africa, and the West Indies. In warm climates it acquires a woody stem, and becomes a tree, rising in India often to a height of thirty feet. Nevertheless, it is still the same plant, and not entitled to be considered as a distinct species, although a woody perennial; the leaves and flowers are unaltered, and the seed, if sown in temperate climates, produces herbaceous plants in every respect the same as those in common cultivation.

Castor oil is obtained by expression from the seeds, without heat, hence it is called "cold-drawn castor oil." The seeds, t up in horse-hair bags, are crushed by the action of heavy iron beaters, and the oil, as it oozes out, is caught in troughs and conveyed to receivers, whence it is bottled for use. Castor oil is brought over from the East Indies in small tin cases, closely soldered, and packed in boxes, weighing about 2 cwt. each. In 1886, 175,813 cwt. were imported into the United Kingdom. Castor oil is much used in medicine, as a mild and certain purgative.

OLIVE OIL (*Olea europæa*, L., natural order, *Oleaceæ*).—The olive-tree is a small evergreen, much branched, and covered with a greyish bark. The olive itself is a drupe or stone fruit, with a fleshy covering, about the size, shape, and colour of a damson. When ripe this fleshy covering contains an abundance of olive oil, which it yields by expression.

The olive is indigenous to Palestine, Greece, and the slopes of the Atlas mountains in Africa. It is now widely diffused in Europe, and is cultivated with great success in Italy, Spain, the south of France, Naples, Sicily, Southern Illyria, Lombardy, and Dalmatia.

The olives are gathered when nearly ripe, and the oil is drawn from them by presses and mills, care being taken to set the mill-stones so wide apart that they will not crush the nut of the fruit. The pulp is then subjected to a gentle pressure, in bags made of rushes, and the best or *virgin* oil flows first. A second oil, of inferior quality, but fit for table use, is obtained by moistening with water the residuum, breaking the nuts, and increasing the pressure; lastly, more water is added, and the residuum is again re-pressed, the product being an impure oil, fit only for soap-making or for burning. Spanish or Castile soap is made by mixing olive oil and soda; and soft soap, by mixing fat, or fixed oil, with potash. The *marc* of olives, as the residuum is called after the oil has been expressed, is valuable either as manure, or as food for cattle.

The virgin oil is called Florence oil, and is imported in flasks surrounded by a network formed of the leaves of a monocotyledonous plant. It is used at the table under the name of salad oil. Gallipoli oil forms the largest portion of the olive oil brought to England; it is imported in casks. Olive oil is largely used in this country in dressing woollen goods, and for machinery. In 1886, 20,064 tuns of this oil were imported into the United Kingdom.

RAPESEED, the seed of *Brassica napus*, L.; natural order, *Cruciferæ*.—This plant grows wild in many parts of England, and is cultivated extensively in this country, in France, and in Germany, for the sake of the oil procured from its seeds. Rape oil is more suitable than any other oil for the lubrication of machinery, and is much used for locomotives, marine engines, and for burning in lamps. A single locomotive consumes from 90 to 100 gallons of oil annually. The consumption of oil by the London and North Western Railway Company alone is every year 40,000 gallons. Good English rapeseed yields an oil very superior to that obtained from foreign rape; nevertheless, in 1886 there were imported into the United Kingdom 372,318 quarters of rapeseed.

LINSEED, the seed of *Linum usitatissimum*, L.; natural order, *Linaceæ*.—We have already described this plant, under the name of flax. Flax seed or linseed yields a most valuable oil, known as linseed oil, largely employed in the arts, especially in painting and in the manufacture of printers' ink. It becomes solid on exposure to the action of the air, or, in other words, is one of the drying oils. Linseed is also extensively used for poultices. This article is always imported in the form of seed. In 1886 the imports into Great Britain were 2,072,011 quarters, principally from the East Indies and Russia.

SESAME (*Sesamum orientale*, L.; natural order, *Pedaliaceæ*).—This is a small showy annual, indigenous to India, and to the whole of Southern Asia, from Japan and China to the shores of the Mediterranean. In those countries it is much cultivated, and the oil, yielded in abundance by the seed, is used for dressing food, and as a common lamp oil. In the East, this oil has some considerable repute as a softener and beautifier of the skin, and as an application to furfuraceous eruptions.

Sesame oil is without odour, and does not easily become rancid. It is frequently used for the adulteration of balsams and volatile oils. Large quantities of the seed are brought to this country from the East Indies and Egypt.

We have now noticed the principal vegetable fixed oils. There are several other oil-producing plants in the market, but not much in demand at present. The following are deserving of notice:—Croton oil (*Croton tiglium*, Lam.). This oil is a valuable and most powerful purgative, capable in over-doses of destroying life, and only administered one drop at a time, in cases where it is of the utmost importance to make a speedy impression on the bowels, and where the patient has difficulty in swallowing. It is also valuable as a counter-irritant. Croton oil is obtained by expression from the seeds. The common hazel-nut (*Corylus avellana*, L.) yields an oil most valuable for the delicate machinery of watches, diminishing the friction of the pinions, the axles of the wheels, and other rapidly-moving parts, which would otherwise wear injuriously, and speedily become disordered. The oil of almonds also is employed for the same purpose. Other oils are obtained from cotton seed, ground n..., carthamus seed, etc.

ELECTRICAL ENGINEERING.—XI.

BY EDWARD A. O'KEEFFE, B.E., A.S.T.E.,

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PRIMARY BATTERIES.

CLASS IV.

CELLS IN WHICH POLARISATION IS PREVENTED BY ELECTRO-CHEMICAL MEANS.

THE distinctive feature of the cells belonging to this class consists in the fact that the negative element is immersed in a solution of its own salt. Polarisation is by this means prevented, and on the negative element a metal similar to itself is deposited instead of hydrogen.

DANIELL'S CELL.

This cell is made up in a number of different forms, that shown in Fig. 23 being an arrangement in which the internal resistance is extremely low. The positive element, Z, is an

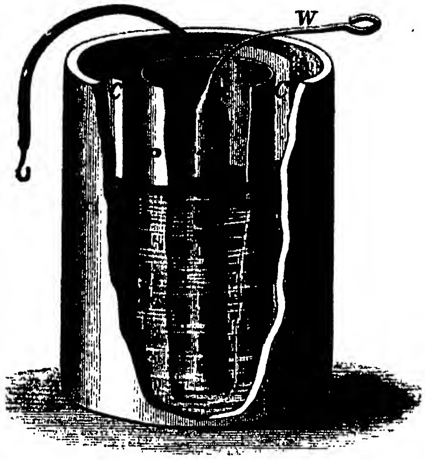


Fig. 23.—DANIELL'S CELL.

amalgamated zinc rod enlarged at the lower end, and having copper wire, W, soldered at the top; this junction should be carefully covered with Chatterton's compound, or some such material. It is immersed in a dilute solution of sulphuric acid contained in a porous pot, P. The negative element, C, is a sheet of bent copper immersed in a solution of sulphate of copper, and the whole is contained in a highly vitrified stoneware jar, J, about 7 inches high.

The E.M.F. of such a cell varies according to the densities of the solutions used, but it may be assumed roughly to be 1·1 volt. This value changes slightly when the cell is in use owing to the densities of the solutions becoming slightly altered, but no polarisation occurs till the sulphate of copper solution has become nearly exhausted. The internal resistance may be as low as ·3 of an ohm, and as high as 1·5 ohm, but it mainly depends upon the areas of the metals, the distance between them, and the thickness and composition of the porous pot. The porous pot is used to keep the two liquids from mixing, but if the cell is allowed to rest for a couple of days they slowly diffuse through it. The immediate effect of this diffusion is to weaken the solution of sulphate of copper in the outer pot, and to deposit a certain amount of pure copper on the zinc. When the sulphate of copper comes into contact with the zinc it is immediately decomposed—owing to the zinc having a higher heat-value than the copper—and the copper thus set free becomes deposited on the zinc in a finely-divided state, having the appearance of black mud. If this operation went on to any considerable extent, the zinc would be eaten away by local action when the cell was not in use. In order to prevent this action from taking place at the base of the zinc—where it is usually most marked—the bottom of the porous pot should be heated and dipped in melted paraffin wax before being placed in the cell.

The chemical action which occurs in this cell can be best described thus:—

Before passing the current:

$Zn + H_2SO_4$ | $CuSO_4 + Cu$
Zinc Sulphuric acid | *Sulphate of copper Copper*

After passing the current:

$ZnSO_4$ $H_2SO_4 + 2\,Cu$
Sulphate of   *Sulphuric acid Copper*

That is to say, the zinc unites with the sulphuric acid to form sulphate of zinc, and hydrogen is set free at the porous partition; this hydrogen unites with the sulphate of copper to form sulphuric acid, and copper is deposited on the copper plate. This action, therefore, tends to burn up the zinc, to change the sulphuric acid into sulphate of zinc, to impoverish the sulphate of copper solution, and to coat the negative element with a layer of pure copper. Polarisation is thus prevented as long as the sulphate of copper is unexhausted, but the E.M.F. of the cell slightly falls when working owing to the aliment being changed from sulphuric acid to sulphate of zinc. In some forms of the Daniell cell the zinc is in the first instance placed in a solution of sulphate of zinc, in which case though the E.M.F. is slightly lower than in the cell just described it is more constant. The chemical action is practically the same, thus:—

Before passing the current:

$Zn + ZnSO_4$ $CuSO_4 + Cu$
Zinc Sulphate of zinc   *Sulphate of copper Copp*

After passing the current:

$ZnSO_4$ $ZnSO_4$
Sulphate of zinc   *Sulphate of zinc*

The only constituent of the cell which thus undergoes any change while working is the sulphate of copper, and this change can be rectified by the addition of a few crystals when the solution becomes impoverished.

This type of cell, or some modification of it, is perhaps more suitable for constant and hard work than any other at present in the market.

THE TROUGH BATTERY.

This battery, which is largely used in the English telegraph service, is a modification of the Daniell. It is made up in a

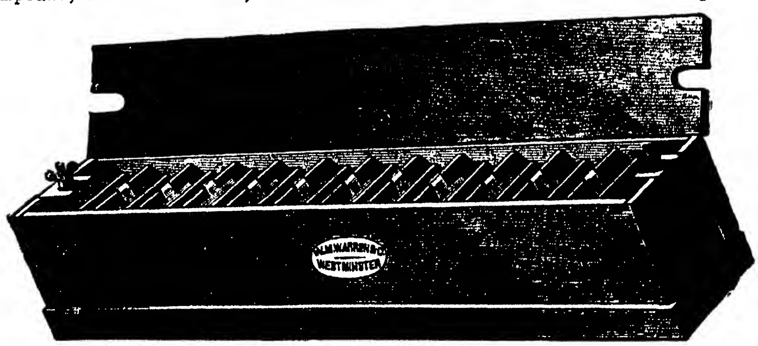


Fig. 24.—THE TROUGH BATTERY.

teak box (Fig. 24), which has been coated inside with marine glue to render it water-tight.

Marine glue is made by dissolving one pound of caoutchouc in four gallons of naphtha, and allowing it to rest for ten days, after which one portion is added to two portions of shellac, and the mixture thus obtained is cooled on marble slabs.

The box is divided into ten or twelve water-tight compartments by slate slabs. Each compartment either contains a flat porous plate, or is divided into two by a porous partition. The reservoirs thus obtained are filled alternately with sulphate of copper and pure water. Into the water dips a zinc plate measuring $3\frac{1}{2}'' \times 2''$, and having attached to it a copper strip, which is bent over the slate slab and joined to a copper plate measuring $3'' \times 3''$ which dips into the sulphate of copper. Ten or twelve such combinations of metals are thus arranged in the trough, the last copper at one end and the last zinc at the other being connected to terminals, which form respectively the positive and negative poles of the battery. In the copper compartment is placed a number of crystals of sulphate of copper to keep up the strength of the solution. This battery is comparatively inexpensive and requires very little attention. The plates might be cleaned about once a month, and crystals of sulphate of copper supplied when necessary; any loss of liquid due to evaporation being remedied by an equivalent supply of water. It has a high internal resistance, and its E.M.F. is scarcely affected by variations of temperature.

MINOTTO'S CELL.

This modification of the Daniell cell (Fig. 25) is made up in a glazed earthenware pot, J J, in the bottom of which is placed

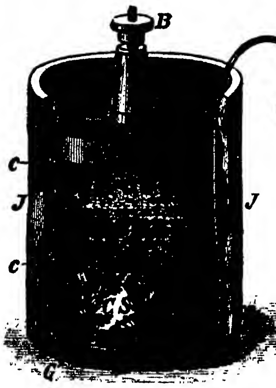


Fig. 25.—MINOTTO'S CELL.

a copper plate, G, to which is attached an insulated copper wire. Upon this plate is placed a number of crystals of sulphate of copper, C S, which are separated from a layer of sand or saw-dust, s, by a piece of canvas, c. Over the sawdust another piece of canvas, c, is placed, and on this rests a zinc disc, Z, having a binding-screw, B, attached. A solution of sulphate of zinc is then poured in so as to cover the zinc disc. This cell has a slightly lower E.M.F. than the ordinary Daniell, and has a resistance which varies between about 10 and 50 ohms according to the dryness and depth of the sawdust. It is very portable, constant, and requires little if any attention.

APPLIED MECHANICS.—VIII.

BY SIR ROBERT STAWELL BALL, LL.D., Astronomer-Royal for Ireland.

THE MECHANICAL PRINCIPLES OF BRIDGES: THE GIRDER—THE WOODEN BRIDGE—THE ARCH.

BRIDGES are of very varied form and construction. A tree which has fallen across a stream is, perhaps, the simplest bridge, and from this natural bridge up to such superb structures as span the Menai Straits, every conceivable intermediate link is to be found. In the present lesson we shall first consider the most simple type of bridge—that of a single beam or girder—and afterwards examine some more complicated constructions of this class.

THE GIRDER.

What is known in Mechanics as a girder will be understood from the accompanying figure. Let P Q (Fig. 1) be a beam, whether of wood, or cast-iron, or wrought-iron. This beam is supported at its extremities by A and B, and from its centre a weight is suspended. Now this weight, if not too large for the strength of the beam, is supported, and the beam is said to be strained transversely. Instead of having one weight attached to the beam, several weights might be suspended from it in different places, as in Fig. 2; or, finally, as in Fig. 3, the beam may be secured by having one end, P, firmly embedded in masonry or some secure support, and have a weight, W, suspended from the other end, Q.

In all these cases, when a beam is strained by a force or forces tending to break it across transversely, the beam is called a *girder*.

We shall first examine the simple case of a beam supported at each end, and bearing a weight in the middle (Fig. 1). When a weight is attached, the beam is seen to bend down a little in the centre; as the weight is increased the curvature increases, until, when the weight reaches a certain amount, the beam breaks.

It will be important for us to determine how the magnitude of the load which will break the beam is connected with its dimensions of length, breadth, and depth. It is manifest that the longer a beam is, the weaker it is, provided its section remain the same. It is easy to prove, in fact, both from theory and from experiment, that the breaking-load of a beam varies inversely as its length. Thus, for example, a beam of wood six inches square and twenty feet long is only half as strong as a beam six inches square and ten feet long. The effect of the section of a beam upon its strength is also to be ascertained without much difficulty. It is well known that a beam whose section is not square is stronger when placed edgewise than when placed flatwise. By actual trial, it will be found that if two perfectly similar and equal beams be taken, and that one beam be broken edgewise and the other be broken flatwise, the load necessary in the former case is to the load necessary in the

Fig. 1.

latter case in the proportion of the depth of the beam to its breadth. From this law, and that which refers to the length, we shall be able to deduce an expression for the breaking-load of any beam of any material, provided that its section be rectangular and constant.

It is a well-known rule among practical men that a beam of cast-iron, one foot long and one square inch in section, is broken by a load of one ton: let us deduce from this result the expression for the breaking-load of any beam of cast-iron which is l inches long, b inches broad, and d inches deep.

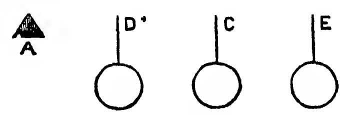


Fig. 2.

A beam whose section was one square inch and whose length was l inches would require a load determined by the following proportion:—

$$l : 12 :: 1 \text{ ton} : \text{answer}.$$

This proportion follows at once, from the law that the breaking-weight is inversely as the length: we infer, then, that for a bar l inches long and one inch square the breaking-strain is

$$\frac{12}{l} \text{ tons}.$$

The beam that we have supposed is b inches broad; it is therefore the same as b beams, each one inch broad, and d inches

Fig. 3.

deep, standing side by side. Hence, the strength of the beam is b times the strength of a beam l inches long, d inches deep, and one inch broad, standing edgewise.

By the second law, a beam one inch broad and d inches deep is d times as strong as a beam d inches broad and one inch deep; and hence the original beam is $b \times d$ times as strong as a beam d inches broad and one inch deep. But a beam d inches broad and one inch deep is d times as strong as a beam of the same length which is one inch square. This is evident, for we may manifestly conceive that d beams, one inch square, placed side by side are identical in strength with the solid beam which

would be formed by making them cohere together. This would not, however, be true of beams placed one over the other. We infer, therefore, finally, that the beam l inches long, b inches broad, and d inches deep is $bd \times d = bd^2$ times as strong as a beam of the same length and one inch square; but we have already seen the strength of the latter to be

$$\frac{12}{l} \text{ tons,}$$

and therefore the breaking strength of the entire beam is

— tons.

This may be expressed in the following manner:—

$$12 \frac{\text{area of section} \times \text{depth}}{\text{length}}.$$

All the magnitudes are to be expressed in inches, and the answer will be in tons.

Example.—To find the breaking-strain of a cast-iron beam twenty feet long, six inches deep, and two inches broad.

The area of section is

$$6 \times 2 = 12 \text{ inches},$$

and therefore the answer is

$$12 \frac{12 \times 6}{240} = 3{\cdot}6 \text{ tons}.$$

The expression we have here deduced for cast-iron holds also for other substances, the only difference being that the numerical co-efficient, which is 12 for cast-iron, must be replaced by one appropriate to the particular material of which the beam is composed.

Thus, in the case of a beam of pine, the breaking-load, expressed in pounds, is given by the expression—

$$6{,}000 \frac{\text{area of section} \times \text{depth}}{\text{length}}.$$

For example, a piece of pine, ten feet long and six inches square, has a breaking strain of

$$6{,}000 \frac{36 \times 6}{120} = 10{,}800 \text{ pounds}.$$

In general, the strength of any beam is represented by

$$S \frac{\text{area of section} \times \text{depth}}{\text{length}}.$$

The values of S for certain substances are given in tables which will be found in treatises on Applied Mechanics.

We have hitherto only discussed the case of Fig. 1, in which the load is applied at the centre of the beam. We have now to consider the case of Fig. 2, where the load, instead of being applied at one point, is distributed over several. A beam in this condition is always able to bear more than when the load is applied entirely at the centre. The most important case which occurs in practice is where the load is distributed uniformly along the beam; as, for example, when a beam, supported at each end, has to sustain the weight of a wall of masonry. In such a case as this every inch of the length of the beam has the same pressure to support. To break a beam by a load applied in this manner requires twice as much weight as when applied at the centre only, and therefore the preceding expression will be applicable if the values of S be doubled.

In large beams the weight of the beam itself forms often a large portion of the load which it has to support, and this pressure is, of course, distributed along the length of the beam. In fact, the dimensions of the largest beams are limited by the consideration that, beyond a certain span, it is impossible to construct a beam which should sustain its own weight.

In Figs. 1 and 2 we have supposed that the ends of the beam are free, and when the beam is loaded the ends curl up slightly. If, however, the ends of the beams be firmly secured by being embedded in masonry, as the end P of the beam in Fig. 3, the strength of the beam is greatly increased, and it will be found that nearly double the load is now necessary to break it than was before required.

The beam of Fig. 3, in which the weight is suspended at one end while the other is fixed, is only one-fourth the strength of a similar beam supported at each end and laden in the centre in the manner represented in Fig. 1.

THE WOODEN BRIDGE.

We shall now examine a few of the simple mechanical principles that are employed in the construction of a timber or iron bridge. The subject is here divested of the complexity which belongs to it in practice, and for information on which reference must be made to actual engineering works. This lesson is rather to be regarded as an illustration of mechanical principles than as a treatise on the building of bridges, which would, of course, be wholly out of place here, and is a difficult subject.

It will be found both easy and instructive to verify experimentally the principles that are here laid down; the apparatus necessary for this is simple and inexpensive. A number of slips of pine half an inch square, and of various lengths, from one foot to four feet, form the only materials necessary for the bridges which will be described in this lesson. These miniature wooden beams are to be fastened together in any positions that may be desired by means of cramps, such as that shown in Fig. 4, and which can be procured in any tool-shop; they should open to about two inches, as sometimes three beams must be fastened by the same cramp. The use of these cramps dispenses with the necessity of any other fastenings, for it will be found that the slips thus fastened together will bear a very great strain, amounting to 100 pounds or more, without slipping. Thus, with the greatest facility, bridges and other structures may be built up, and actually loaded with considerable weights, 14 pounds, 28 pounds, 56 pounds, etc., to test their strength. Possessing a few dozen of these slips of wood, and a corresponding number of cramps, many varieties of simple bridges may be tested, the same slips re-appearing in different combinations; and the apparatus may also be used for constructing models of roofs, and many other pieces of framework which will suggest themselves to the inquiring student. It will probably be found surprising what efficient joints are produced by the compression of the wood in the cramp; but, in cases of very great strains, the danger of slipping will be lessened by interposing two small pieces of sand-paper, back to back, between the surfaces of wood in contact. A few larger cramps will often be found useful for securing the important joints more firmly than is possible with the small cramps; the bruising of the slips may be diminished if necessary by the interposition of small slips of card-board between the iron and the wood.

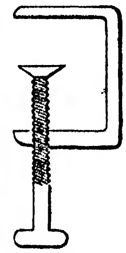


Fig. 4.

Let us suppose that it is desired to make a foot-bridge from one support, A, to another, B (Fig. 5). The most simple way of doing it, if the distance be not great, is to lay a plank of sufficient strength across, with its ends on each support; and for a short distance no method can be more efficient. To consider the strength of such a bridge, we must remember what has been already proved, that the load being the same, the weakness of the bridge increases proportionally to its length, and hence we see that the longer is the distance from A to B, the stronger must the planks be; but with an increase in the strength—that is, in the dimensions of the plank—there is a corresponding increase of its weight, and therefore an addition to the load which it has to sustain. When to this we add that there is, of course, a practical limitation to the magnitude of planks, we see at once that when the distance between A and B exceeds a certain amount, a bridge consisting of a single unsupported plank is a practical impossibility. It will be found that a slip of pine half an inch square, and resting on two supports, the distance between which is ten inches, would be broken by suspending a weight of about 80 pounds, more or less, according to the quality of the wood, at its middle point; hence we should infer, and we can easily verify by experiment, that a rod of the same wood resting on two supports forty inches distant, would be broken by a weight of about 20 pounds. We shall then examine the means by which a bridge consisting of a single plank can be strengthened. For convenience, we shall confine our attention to the rod of pine half an inch square and four feet long, being one of those with which the experiments are made, and, of course, the observations will apply, *mutatis mutandis*, to every other case.

Let A B be a single beam, which is too long when unsupported

to form a safe bridge for the load which it has to carry. If, by means of a pedestal, it could be directly supported at the middle, at the point X, its strength would be doubled, because then it would be equivalent to one beam, A X, resting on the supports A and X, and to another, B X, resting on B and X; and since the strength of a beam varies inversely as its length, each of these portions is twice as strong as the whole beam was before, and therefore the bridge will now support double the weight which it could carry originally.

If three pedestals are applied, the length A B is divided into four parts; each part is, therefore, four times as strong as the unsupported plank A B, and therefore the supported bridge is four times as strong as it was before the pedestals were applied to it.

Whenever it is possible to have a number of pedestals under a bridge, they form the most suitable and efficient means of support, but in the majority of cases it will not be possible, and other means of support must be sought.

If a rod of pine four feet long be supported at the ends A and B, it would sustain about 20 pounds hung at its middle. Let the points of trisection, P and Q, of this beam be taken. If these points could be firmly supported, we should then expect, according to the principles already explained, that the strength of the rod would be increased threefold. Now, if with the help of cramps another rod be fastened to A B at P, and to the support at C, and a second rod, Q D, be similarly attached, the desired object is accomplished.

It will be found on trial that the sustaining power of the

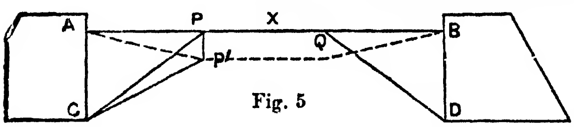


Fig. 5

bridge has been vastly increased, and it will also be noticed that, whereas before it yielded and bent under a slight load, it has now acquired considerable stiffness and rigidity. What is the reason of this? The point P could formerly be pressed downwards a little without breaking the beam, and on the relaxation of the pressure it returned, of course, to the horizontal line. Let us suppose that it could be pressed down to P′. P P′ is vertical, for the ends A and B being secured, P could not be pushed either towards A or B, but only vertically. In the triangle C P P′ the angle C P′ P is the greatest, and therefore C P is greater than C P′. Hence P cannot be depressed at all without coming nearer to C; but when the rod C P is introduced, and firmly fastened both at C and P, it prevents P coming any nearer to C, and therefore P cannot move at all, provided the joint do not slip nor the pressure be sufficient to break C P. In fact, A P C may be looked upon as a triangle on the base A C; and since, by Euclid I. 7, there cannot be two triangles on the same base and same side of it which have their conterminous sides equal, it follows that P cannot move when C P is applied, though the flexibility of the wood would have allowed it to do so previously. In precisely the same way it can be shown that Q is a fixed point. Hence the beam A B may be regarded as directly supported at P and Q, and therefore the whole will be as strong as each of the three equal segments into which it is divided. Hence, by the principle already explained, the strength of the bridge is increased threefold. Actual experiment will be found to justify this reasoning. By placing a second four-feet rod parallel to A B, and distant from it by a few inches, and similarly supporting it by two other rods, and then laying a few short rods crossways over both beams to form a roadway, the bridge can be loaded with weights to test its strength.

THE ARCH.

The simplest theory of the arch is that which is given by Dr. Hooke. A chain which is suspended from two points hangs downwards in a curve called the *catenary*, and each of its links is retained in equilibrium by the tension of the two adjacent links which counterbalance its weight. Precisely similar is the equilibrium of the stones which form an arch. Each of the stones is held in equilibrium by the pressure of the two adjacent stones, called voussoirs, and its own weight. The difference between the cases is, that while the equilibrium of the chain is unstable that of the arch is stable.

NOTABLE INVENTIONS AND INVENTORS

VII.—THE MARINER'S COMPASS (*concluded*).

We now resume the history of the compass. In 1280, when Marco Polo returned from his travels in Cathay, he is believed to have brought a knowledge of the compass, as well as other Chinese inventions, back to Europe with him; but there is no known authority for this opinion that can lay claim to authenticity. It is certain, however, that before the close of the fifteenth century, when Vasco de Gama found his way round the Cape of Good Hope, the pilots of the Indian seas were expert in the use of sea-charts, the astrolabe, and the compass.

We find the compass minutely described by Guyot de Provence, in his satire, "Le Bible," about the year 1190. Guyot, a minstrel by profession, had probably seen it in use during the Crusades, to one of which, most likely, he had previously attached himself. At all events, Cardinal de Vitry and Vincent de Beauvais, both Frenchmen, and both Crusaders, writing at a later period by a quarter or half a century than Guyot, speak of it as a great curiosity which they saw in the East, and we may infer that it was a thing almost unknown in Europe. There is not, hence, the slightest foundation for the belief that it was used by European seamen at so early a period, though there can be but little doubt that by the middle of the thirteenth century it had come into partial use, and into general knowledge; since, in one of the songs of Gauthier d'Epinoir, is an *allusion* which no one would have made, had not his auditors been familiar with the magnetic needle.

It was long contended that the inventor of the compass as a nautical instrument was Flavio Gioja, a native of Amalfi, near Naples; and the date given by the Italians is from 1300 to 1320. It is obvious, from what we have already said, that there is no foundation for this opinion. Before this assigned period, even the "Tresor" of Brunetto Latini (the master of the divine Dante) bears evidence that the compass was not a rarity. It is, however, highly probable that Gioja greatly improved the compass, either by its mode of suspension, or by the attachment of the card to the needle itself, or in some other important particular.

The French long laid claim to the discovery of the compass, or at least to the attachment of the card to the needle, from the circumstance of the north point being marked with the *fleur-de-lis*; but there is no distinct evidence on this point, and Sir John Davis, with more probability, considers that the figure is an *ornamental cross*, originating in the devotion of an ignorant and superstitious age to the mere symbol. Besides, this ornament is not peculiar to the compass, but may be seen on the hour-hand of modern French clocks. Or, as Sir John observes, "as the compass undoubtedly came into Europe from the Arabs, the *fleur-de-lis* might possibly be a modification of the *monasala* or dart, the name by which the Arabs called the needle." Still, the *fleur-de-lis*, as the ornament of the northern radius of the compass, is said to have been adopted by Gioja, the Neapolitan, because it was the device of the reigning King of Sicily at the time Gioja first employed the instrument in navigation.

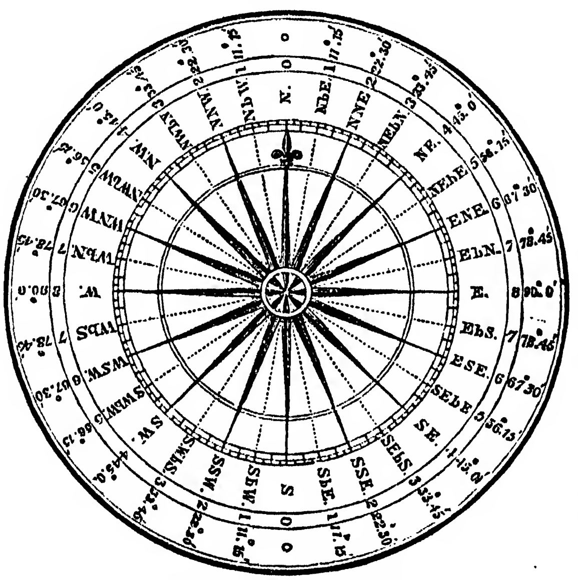
By whom the suspension now generally used was invented, is altogether unknown from any document or other evidence. We have already explained that a magnetic needle balanced on a pivot will, subject to a correction for the variation of the magnet, point out the true direction of *north* and *south*. A card, bearing the points of the compass, and unalterably attached to any apparatus, such as a globe, will therefore afford the means of adjusting it north and south, if the centre of the card be made the pivot of a magnetic needle. In the mariner's compass, however, we affix the needle to the card, pointing it towards north and south, so that the card travels with the needle; and if a pointer (fixed with respect to the ship) mark out the point on the edge of the card, which lies in the line drawn through the pivot parallel to the plane which symmetrically bisects the ship, the bearing of the ship's head is shown by that part of the card to which the pointer directs for the time being. To ensure the horizontality of the compass-card, the cylindrical box in which it is enclosed is supported in a hoop at opposite points by pins projecting from it, so as to allow the box to revolve inside the hoop. This hoop is supported in the same manner on pivots, the line of which is at right angles to the first points; so that by the rotation of the compass-box in the hoop, and of the hoop itself, the former can always form its position of equilibrium, which is

the horizontal position. The small oscillations of the apparatus are immediately destroyed by the friction. The apparatus is then said to be supported on gimbles, or gimbals, allowed to have been the invention of an Englishman.

The *dip of the needle*—that is, the angle which, when supported on its centre of gravity, it makes with the plane of the horizon—was discovered by Robert Norman, of Wapping, in 1594. Next was discovered the variation of the compass; that is, that it did not point directly to the north, but somewhat east of that point. To account for this it was supposed that the magnetic pole of the earth did not coincide with that of the axis on which the globe itself turned, and so it proved.

The *variation of the needle* was known to a Chinese philosopher, who wrote about the year 1111. Columbus was sailing across the Atlantic Ocean, in his attempt to find a new world. On September 13, 1492, in the evening, being about two hundred leagues from the island of Ferro, Columbus first noticed the phenomenon: the variation was a little to the west at London. About nightfall, the needle, instead of pointing to the North star, varied about half a point, or between five and six degrees to the north-west, and still more on the following morning. Columbus was struck with the circumstance, and he observed the variation to increase three days as he advanced. He at first made no mention of the phenomenon, knowing how ready now his people were to take alarm; but the pilots were filled with consternation. It seemed as if the very laws of Nature were changing as they advanced, and that they were entering another world subject to unknown influences. They apprehended that the compass was about to lose its mysterious virtues, and without this guide what was to become of them in a vast and trackless ocean! Columbus now sought to allay their terrors. He told them that the direction of the needle was not to the Polar star, but to some fixed and invisible point; the variation was not caused, therefore, by any fallacy in the compass, but by the movement of the North star itself, which, like the other heavenly bodies, had its changes and revolutions, and every day described a circle round the pole. The pilots had faith in Columbus, and believed him. Hi explanation, as the Copernican system was unknown, was plausible, and was believed; and it showed Columbus's readiness to meet the emergency. The phenomenon has now become familiar to us, but we are not so cognisant of its cause. "It is," says Washington Irving, "one of those mysteries of Nature open to daily observation and experiment, and apparently simple from their familiarity; but which, on investigation, make the human mind conscious of its limits, baffling the experience of the practical, and humbling the pride of science."

The iron employed so extensively in modern vessels has created great, but generally unsuspected, deflections of the magnetic needle from the position which, under the influence of terrestrial magnetism only, it would take in any given place and at any given time. Numerous vessels have been wrecked in consequence of this alone. In England, the errors of the compass from the action of iron have been corrected by placing near it powerful magnets, the action of which produces upon the needle equal effects, but opposite to those of the ship. The French employ a table of corrections, based upon minute observation, and applicable to every indication of the compass affected. Nevertheless, fatal accidents are still attributable to the errors of the compass. One of the contrivances for diminishing this serious inconvenience is the correcting compass, which affords the means of taking the sun's position, whereby the deviation may be corrected. Lightning alone exercises a decided influence on the needle, by reversing its points, so that north becomes south, and conversely. When a vessel is nearing land, the needle is said to be affected; and certain rocks exercise a decided magnetic influence on the compass, volcanic rocks especially, but this influence is not felt on board ships. But the action of the iron forming the ship's sides is far different; nothing, not even the interposition of a thick non-magnetic body, will stop its influence. But the real danger proceeds from another source; since the ship herself, under her weight of canvas, may increase the deviation of the needle. From experiments made on board an iron-built sailing vessel, provided with iron rigging and lower yards of steel, and with two binnacle compasses on her poops, and a third placed between the mizen and main masts, the lower part of which was all of iron, the deviations of the needle were respectively 56°, 24°, and 35°. It need scarcely be added that much experience may be gained by freighting an iron vessel only when she has been at sea for a considerable time, in order to ascertain how her compass behaves. The Rev. William Scoresby, whom we have already mentioned, published his various investigations of the influence of iron ships upon their compasses, and the requisite corrections. One of the most interesting of these we have described in the previous number. In 1855 Dr. Scoresby communicated to the British Association a summary of his matured views and the evidence in their favour, in which he recalled attention to his plan of *a compass aloft*, which affords a simple and effective mode of ascertaining the direction of a ship's course; and to exemplify this and other questions, Dr. Scoresby, in 1856, took a voyage to Australia in the *Royal Charter* iron steam-ship. His theory proved correct. But the fatigue of the voyage to a man approaching seventy years of age was excessive, and, without doubt, accelerated his death. As a proof of his energy in the cause of science, it may be mentioned that once in the course of this voyage, in a violent cyclone, he ascended the mizen-rigging to judge of the height of the waves, which he calculated to be then thirty feet. He returned to England, and narrated his voyage to a large audience at Whitby; but while preparing his journal for publication he died, leaving his widow to receive, as a memorial of his services, a chair formed from timber of the vessel in which he made his voyage to Australia.



THE MARINER'S COMPASS.

In reviewing the history of the compass, we are reminded of the remark of Sir John Herschel—that such inventions are not the creation of a few years, or a few generations. They presuppose long centuries of previous civilisation, and that, too, at the dawn of European history, when the declination of the needle was known.

The following facts relative to the construction of the mariner's compass, the graduated card of which is shown in the annexed illustration, may prove interesting to the reader:—The shape of the needle is generally that of a long parallelogram, of which the width is very small in comparison with the length: or that of an elongated lozenge. A hollow cone, generally of steel, but sometimes of agate, rises precisely in the centre of the needle to supply the means of balancing it on the fine point of the pin on which it works, and about which it may turn freely in any direction without the slightest hindrance from friction.

The pin on which the needle works rises perpendicularly from the centre of a circular card, marked as in the illustration. The central portion of the card, lying within a graduated ring divided into 128 parts, is marked with a star of 32 rays, of

16 are solid and 16 dotted. These rays mark the 32 points the compass, the ray that marks the north point on the card being distinguished by a *fleur-de-lis*. The graduated ring already spoken of shows the division of each of the 32 points into quarter-points. In the ring or belt immediately without it is marked the reading of each point. In the narrow ring immediately without this is marked the numerical order of the points from north and south to east and west on either side; and in the outermost ring is given the value of each point from north and south to east and west on either side in degrees and minutes, each point being equal to the 1-32nd part of 360 degrees, or 11° 15′.

ANIMAL COMMERCIAL PRODUCTS.—XIV.

III.—EDIBLE SPECIES.

The preceding notice of the Mollusca would be incomplete without some reference to their value as a source of human food. Amongst the edible kinds we have the

Oyster (*Ostrea edulis*).—Vast beds of this mollusk are planted and tended with great care. The oyster culture is carried on most extensively at Colchester and other places in England, and on the coasts of France. The oysters are laid in beds, in creeks near the shore, where in two or three years they grow to a considerable size, and improve in flavour. Between 14,000 and 15,000 bushels of Essex oysters are consumed in London annually. There are 200 vessels, of from twelve to fifty tons' burden, manned by 400 or 500 men and boys, continually dredging for oysters on the Essex coast.

Mussel (*Mytilus edulis*).—This is another popular mollusk, not so digestible as the oyster, but nevertheless in considerable demand as human food, and largely employed as bait for whiting, haddocks, and cod. We have also the *Cockle* (*Cardium edule*), *Periwinkle* (*Littorina littorea*), *Whelk* (*Buccinum undatum*), and the *Ormond Whelk* (*Fusus antiquus*), with which our markets are abundantly supplied. Others might be mentioned, but enough has been said to show that, whilst the shell of the mollusk is attractive and useful, the soft body of the creature that dwells within it is not less valuable.

PRODUCTS OF THE SUB-KINGDOM ANNULOSA.

Annulosa (Latin, *annulus*, a ring), a name given to the third great division of the animal kingdom. The body, in *Annulosa* generally, presents a symmetrical form, and consists of a series of rings or segments; the nervous system is a double nervous thread, which extends along the body at its lower side, and is united at certain distances by double "ganglia," as these nervous masses are termed—nerves being given off from these ganglionic masses. In the group *Annuloida*, the body is ringed and devoid of limbs, whilst in the *Articulata* it is composed of movable pieces, and the limbs are jointed.

The Annulosa are divided into the following classes:—

1. *Annelida* (Latin, *annulus*, a little ring), animals having bodies soft and pliable, more or less cylindrical, and formed of a great number of small rings. Examples: earthworm and leech.

2. *Crustacea* (Latin, *crusta*, a hard covering), having an articulated, hard shelly case or covering, in which the softer parts of the body are contained. Examples: crabs, lobsters, etc.

3. *Arachnida* (Greek, *arachne*, a spider), having the head and thorax confluent with each other, and the body consequently consisting of only two segments, with eight legs, and smooth eyes. Examples: spider and scorpion.

4. *Insecta* (Latin, *in*, into, and *seco*, I cut), including those animals having an insected or divided appearance of the body into three well-marked portions, called respectively the head, thorax, and abdomen. Six legs are articulated with the thorax. Examples: bee, moth, and beetle.

In the first class, *Annelida*, we have one species of very considerable value in commerce, the

Leech (*Hirudo medicinalis*, L.).—This is an abranchiate red-blooded worm, provided with a circular disc or sucker, at either extremity of the body. The oval aperture or mouth is formed of three pairs of cartilaginous jaws, each armed with two rows of very fine teeth, and disposed in such a manner that they form three radii of a circle. This apparatus enables the leech so to penetrate the skin as to ensure a ready flow of blood without causing a dangerous wound. Leeches are usually found in pools and marshes, sometimes in England, but principally on the Continent, especially in Portugal, the south of France, Germany, Hungary, and Russia. The greatest quantities come through Pesth and Vienna from Hungary. Most of the leeches used in England are imported from Hamburg, whither they are sent from the lakes of Pomerania and Brandenburg, and from the province of Posen in Prussia.

Leeches are taken by men, who wade into the pools with naked legs, to which they fasten themselves. The men then leave the water, and remove them before their bites become injurious. Leeches are sent over in bags, or more frequently in small tubs, closed with stout canvas to allow a free passage of air. Each tub usually contains about 2,000 leeches. Some idea of the extensiveness of the leech trade may be obtained from a fact mentioned by Dr. Pereira, that, some years ago, "four principal leech dealers in London imported on the average 600,000 leeches monthly, or 7,200,000 annually." The annual consumption of leeches in Paris is estimated at 3,000,000, and that of the whole of France at 100,000,000.

The second class, *Crustacea*, furnishes several species which are used as food—as crabs, lobsters, crayfish, prawns, and shrimps, so well known as to render description needless. Omitting the Arachnida, which are of no commercial value, we come to the fourth class, *Insecta*, which is pre-eminent over the others in the number of individuals, and in their beautiful forms, colours, and transformations. Its members are in the highest degree valuable to man, furnishing him with unlimited supplies of honey, wax, silk, and dyeing materials. The following are the most important insects, regarded from a commercial point of view.

The *Silkworm Moth* (*Bombyx mori*) belongs to the family *Bombycidæ*, a section of the nocturnal lepidoptera or moths. It has short plumose antennæ, a thick short body, stout legs, and white wings, with two or three dark lines stretching across them parallel to the margin. It lays its eggs, which are of a greyish tint, on the leaves of the mulberry tree (*Morus alba*), upon which the larva feeds. These larvæ form the cocoons from which the silk is procured. The eggs may be preserved a long time without deteriorating, provided they are kept free from damp, and not too many in the same packet. The eggs in this state are called by the silk cultivators "seed."

The larvæ when first hatched are a quarter of an inch long and of a dark colour, and the first care after their birth is to separate them from their shells, and place them in hurdles where they may find appropriate food. For this purpose, a paper perforated with holes and covered with mulberry-leaves is spread over the basket in which the larvæ are placed, and in passing through the holes to get at the mulberry-leaves, they free themselves from their shells. The silkworm lives in the larval state from six to eight weeks, during which time it moults or changes its skin four times, increasing in size and voracity with every moult, and when fully grown is about three inches in length.

The caterpillar now stops eating, betakes itself to some convenient spot where, after spinning a few threads in various directions, it suspends itself in the midst of them, and by continually twisting its body, it gradually envelopes itself in a thick, silken, oval-shaped cocoon. The silk is a secretion of a pair of tubes called *sericteria*, which terminate in a prominent pore or spinneret on the under lip of the caterpillar. The two fine filaments from the *sericteria* are glued together by another secretion from a small gland, so that the apparently single silken thread proceeding from the caterpillar, which forms the cocoon, is in reality double. Whilst spinning the cocoon, which is usually completed in five days, the larva decreases in bulk, casts its skin, becomes torpid, and ultimately assumes the chrysalis form in the interior of the cocoon.

The cocoons, when completed, are thrown into warm water, which dissolves the glutinous matter that causes the threads to adhere, and separates them. The end of the thread is then found, and placed upon a reel; the silk is wound off the cocoon and formed into hanks. When this is carefully done, the silken thread obtained from a single cocoon is sometimes from 750 to 1,150 feet long, or of an average length of 300 yards. Twelve pounds of cocoons yield 1 pound of raw silk. About 1 ounce of silkworms' eggs will produce 100 pounds of cocoons; 16 pounds of mulberry leaves are food sufficient for the production of 1 pound of cocoons; and each mulberry tree yields about 100 pounds of leaves. These data afford the reader the means of cal-

culating the number of insects, eggs, trees, and leaves necessary for the production of the 2,230,900 pounds of raw silk, the quantity that was imported into the United Kingdom in 1886.

The art of rearing silkworms, of unravelling the threads spun by them, and manufacturing those threads into articles of dress and ornament, seems to have been first practised by the Chinese. In China, Japan, and India, silk has formed, from time immemorial, one of the chief objects of cultivation and manufacture. The silkworm moth and the mulberry tree are, in fact, both natives of China, and a great portion of our supplies of silk is still derived from that country. There was a time when silk, now so abundant, was valued in Rome at its weight in gold, and the Emperor Aurelian refused his empress a robe of it on account of its dearness. At the period when our ancestors were naked savages—2,000 years ago—the Chinese peasantry, amounting in some provinces to millions in number, were clothed in silk.

From China the cultivation of silk extended to Hindostan, and thence to Europe, in the reign of the Roman Emperor Justinian, about the middle of the sixth century. From the sixth to the twelfth century the culture of silk was confined to Greece, particularly to the Peloponnesus, where it spread so much that this part of Greece derived its modern name, Morea (Latin, *morus*, a mulberry), from that circumstance. From Greece silk cultivation spread into Sicily, Italy, Spain, and finally France. The French commenced its culture in 1594, under the auspices of Henry IV., and the raising of raw silk and its manufacture now form a very considerable proportion of the French trade. We have not space for further detail of the progress of the silk manufacture.

At present the United Kingdom is supplied with the raw material for manufacture principally from China, the East Indies, the Levant, France, and Italy. Of Chinese silks the best come from the provinces of Nankin and Tsekiang in Eastern China. Silk of an inferior character is received from Southern China, through Canton. The principal ports from which we receive East Indian silk are Calcutta and Bombay. The exports from these places amount to 10,000 cwt. annually. Anatolia and Syria produce much good silk, principally around Damascus and Beyrout; this goes chiefly to Western Europe, *viâ* Aleppo, Smyrna, and Constantinople. A great deal of Persian and Armenian silk is brought by caravans from Asia, by Bassora, Bagdad, Damascus, etc., to the ports of the Levant, and goes by the name of silk of the Levant. This name also includes all the silk produced in Turkey, the Morea, and in the Archipelago, and brought into commerce through Gallipoli and Salonica. As the breeding of silkworms only prospers in warm climates, silk culture is confined in Europe to Italy, the South of France, and Spain. There is also considerable silk cultivation on the southern slopes of the Alps, in Tyrol and Illyria, and within the last twenty years successful attempts at silk culture have been made in Bavaria and Lower Austria.

SILKWORM-REARING ESTABLISHMENT.

As already stated, the quantity of raw silk imported into Great Britain in 1886 was 2,230,900 pounds, and the value of the silk manufactures imported in that year was £10,683,655. Although the climate of England is too cold to rear the silkworm, we are able to manufacture the silk. We have upwards of 300 silk manufactories, giving employment to 50,000 hands. The principal seats of the English silk manufacture are:—For broad silks, Spitalfields, Manchester, Macclesfield, Glasgow, Paisley, and Dublin; for crapes, Norfolk, Suffolk, Middlesex, Essex, and Somerset; for handkerchiefs, Manchester, Macclesfield, Paisley, and Glasgow; for ribands, Coventry; for hosiery, Derby; and for mixed goods, Norwich, Manchester, Paisley, and Dublin. The annual value of the goods manufactured is computed at £10,000,000. The exports of British manufactured silks are chiefly to the United States and the colonies. We also ship silks extensively to South America, Germany, Belgium, and even India and France.

Next to the silkworm moth the *Honey Bee* (*Apis*

is the most useful insect to man. This insect belongs to the order *Hymenoptera* (membrane-winged), an order characterised in most of the genera by the presence of a sting. The habits of the honey bee are replete with interest, arising from its social economy and from the separation of the individuals into three communities based on sexual modification, viz., the queens, or prolific females; the workers, or barren females; and the drones, or males.

The hive bee or honey bee is distinguished from the other species of *Apis* by having the femora of the posterior pair of legs furnished with a smooth and concave plate on the outer surface, which, fringed with hair, forms a basket adapted for the conveyance of pollen. A swarm of bees consists generally of about 6,000 individuals, of which about one-thirtieth part are males, the rest females, and of these one only is for the most part prolific, called the "queen." The body of the queen bee is longer, her colours brighter, and her head smaller than these parts in the other bees, and her sting is curved. The male bees or drones have no stings; their body is shorter and thicker. The workers have a straight sting, but as their growth is arrested before the full development of all their organs, they are smaller than either the queen or the drones, and their colours are less bright. The honey bee in its natural state generally constructs its nest in hollow trees, but throughout Europe it is now rarely found except under domestication.

The comb consists of beautiful hexagonal cells, placed end to end in such a manner that each cell is closed by three waxen plates, each of which also assists in completing one of the cells of the other side of the comb. The whole duty of the construction of the comb and the care of the young devolves upon the workers, whose incessant activity has rendered them the symbol of industry.

It is a remarkable fact that we derive the greater part of our knowledge of the economy and habits of the hive bee from the labours of a blind man. The elder Huber lost his sight when only seventeen years of age, but by means of glass hives, variously constructed, he was enabled, through the aid of his wife, to become acquainted with all that was going on in them, and from her faithful recital of what she saw, together with the aid of an untiring investigator, M. Burnens, he amassed the material for his celebrated work.

In the construction of the comb the bees take hold of each other, and suspending themselves in clusters, which consist of a series of festoons or garlands crossing in all directions, remain immovable for about twenty-four hours, during which time the wax is secreted in the form of thin plates from between the scales of their bodies. One of the bees makes its way to the roof of the hive, and detaching its plates of wax in succession from the abdomen with the hind legs, works them up with the tongue into the material which forms the comb; this bee is followed by others, which carry on the work. As soon as a few cells are thus prepared, the queen bee begins to exude her eggs. The first eggs develop into workers, the next produce the drones and also the queens. The eggs are deposited in the cells, and in five days the maggot is hatched. The sole employment of the queen bee is the laying of these eggs, and as only one is deposited in each cell, this occupies her almost incessantly. The queen, when thus engaged, is accompanied by a guard of twelve workers, who clear the way before her, and feed her when exhausted, always with the utmost courtesy turning their faces towards her, and when she rests from her labour, approaching her with humility. She "lays workers' eggs for eleven months, and afterwards those which produce drones. As soon as this change has taken place, the workers begin to construct royal cells, in which, without discontinuing to lay the drones' eggs, the queen deposits, here and there, about once in three days, an egg which is destined to produce a queen. The workers' eggs hatch in a few days, and produce little white maggots, which immediately open their mouths to be fed; these the workers attend to with untiring assiduity. In six days each maggot fills up its cell, it is then roofed in by the workers, spins a silken cocoon, and becomes a chrysalis, and on the twenty-first day it comes forth a perfect bee. The drones emerge on the twenty-fifth day, and the queens on the sixteenth."*

* "Familiar Introduction to the Study of Insects." By Edward Newman, F.L.S.

ELECTRICAL ENGINEERING.—XII.

BY EDWARD A. O'KEEFFE, B.E., A.S.T.E.,

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PRIMARY BATTERIES.

CLASS IV. (*continued*).—GRAVITY DANIELLS.

In these cells the liquids are kept separated, without the aid of any porous partition, by means of the different densities of the solutions employed. Fig. 26 shows the Callaud cell, and Fig. 27 the Lockwood cell, both acting on the gravity principle. The lower liquid is in each case a saturated solution of sulphate of copper, and the upper liquid may be either water or sulphate of zinc. In the Callaud cell both zinc and copper are in the form of cylinders. The copper rests upon the bottom of the glass jar, and has an insulated wire, *Cu*+ (Fig. 26), passing up through the liquids and forming the positive pole. The zinc cylinder is suspended from the rim of the jar; a wire, *Zn* —, attached to this cylinder forms the negative pole. The glass jar is about eight inches high, the dimensions of the other portions of the cell being approximately as shown in Fig. 26. The copper solution should be renewed every two or three months, and the zinc cylinder cleaned from any copper mud which may have been deposited on it. Any loss of liquid due to evaporation should be compensated by the addition of water.

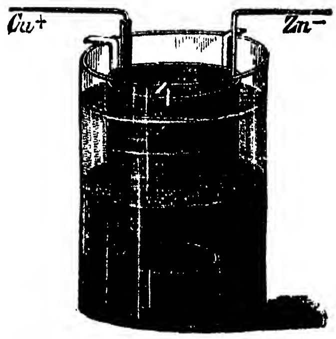


Fig. 26.—CALLAUD C

The arrangement of the metals in the Lockwood cell (Fig. 27) is similar to that in the Callaud. The copper is in the form of two wire spirals, one of which rests on the bottom of the jar and supports the other on a wire joining their centres. The space between these spirals is filled with crystals of sulphate of copper, and above the upper one is a solution of sulphate of zinc, in which is immersed the zinc element in the form of a wheel with spokes. The axis of this wheel forms the negative pole, whilst an insulated copper wire passing through the liquids and attached to the spirals forms the positive one. The glass jar is about ten inches high, the other dimensions being as shown in Fig. 27. A thin layer of oil is floated on the sulphate of zinc in order to check the evaporation of the liquid.

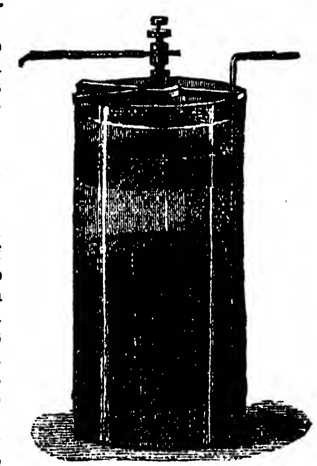


Fig. 27.—LOCKWOOD CELL.

The cells have the same E.M.F. as the ordinary Daniell, and a high internal resistance. As compared with other cells, they are inexpensive, zinc and sulphate of copper being the only materials used up. They are easily made up and easily cleaned. On the other hand they are not portable; in fact, after having once been made up they should never be disturbed. Any motion of the cell will cause the mixing of the two solutions and the consequent deposit of the black copper mud on the zinc. Even when the cell is kept stationary this mixing of the liquids is not altogether avoided; they slowly mix by diffusion, and hence the necessity for cleaning the zinc at intervals. In the

Lockwood cell the object of the upper copper spiral is to prevent this diffusion of the liquids, which it does to some extent, but not entirely. This diffusion appears to take place principally when the cell is not in use, and it can be partially prevented by making the cell send a very small current continuously. For a hard-worked telegraph line or a central testing station these cells may be used with advantage, but their comparatively high internal resistance renders them useless for the supply of large currents.

A modification of the Gravity Daniell, known as the *tray type*, due to Sir William Thomson, has an extremely low internal resistance, owing to the large surfaces of the metals used and the short distance between them. Fig. 28 shows a number of these cells arranged in series. A is a wooden tray

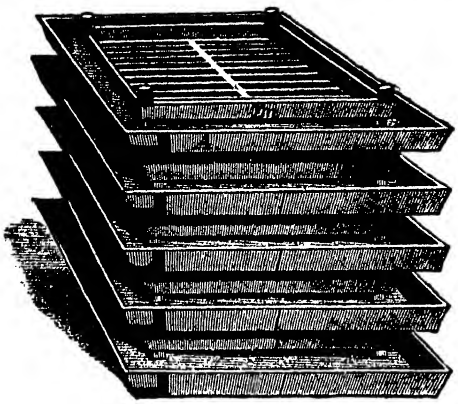


Fig. 28.—THE THOMSON PILE.

lined inside with lead, on which has been deposited electrically a coating of copper, *Cu*. Into this tray a saturated solution of sulphate of copper is poured, and on it rests a layer of water or a solution of sulphate of zinc. *Zn* is a zinc grid resting at the corners on four blocks of wood or vitrified earthenware, and immersed in the solution of zinc sulphate or water. In some forms a piece of parchment separates the liquids, but this is not necessary, owing to their different densities. The zinc being in the form of a grid, exposes more surface for working purposes, and allows the liquid to circulate more freely than if it were a plain plate. A sheet of lead is used in many modifications of the Daniell as the negative element, as it becomes coated with copper during the ordinary working of the cell, and it is cheaper in the first instance. Connection is made between the separate cells by means of lead strips; and care must be taken when arranging them in piles that they lie horizontally, so as to preserve a uniform depth of liquid about each metal. The trays are made about twenty inches square, and the internal resistance may thus be reduced to a quarter of an ohm.

Owing to the large extent of the liquid surface exposed to the action of the atmosphere in these cells, evaporation is very marked. The sulphate of zinc then becomes too concentrated, and crystallises on the sides of the trays. The liquid passes up by capillary attraction between the crystals and the sides of the cell until the whole of the sides have become covered with crystals. This creeping of the crystals also takes place down the outside of the cells and forms a kind of syphon which draws off the liquid. This action can be partially prevented by covering the upper portions of the cells before they are made up with paraffin wax.

DE LA RUE'S BATTERY.

The metals used in this battery are zinc and silver. The zinc, which is the positive element, should be pure, unamalgamated, and immersed in a solution of chloride of zinc, which acts as the aliment. The silver used should be a thin strip surrounded by a stick of fused chloride of silver. Both are contained in a small cylindrical glass vessel, about four inches high and one inch in diameter, the mouth of which is closed with a paraffin plug. Fig. 29 shows a battery of ten such cells connected up in series, and arranged in a convenient form. When in action the zinc is burnt up, the chloride of silver becomes reduced, and pure metallic silver is deposited on the silver strip; polarisation is thus prevented, a larger surface of the negative element is exposed, and the resistance of the cell correspondingly diminished. The E.M.F. of each cell,

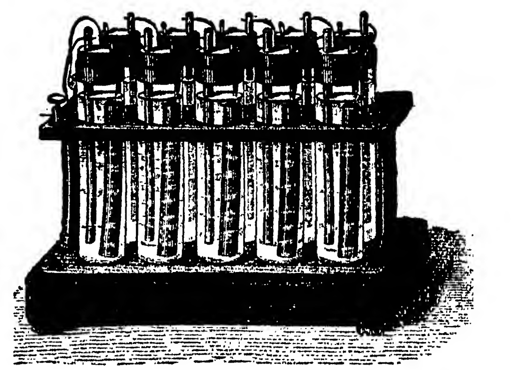


Fig. 29.—DE LA RUE'S BATTERY.

which is remarkably constant, is 1·046 volt, and the internal resistance about 5 ohms. The battery requires no attention, except the replacing with pure water any liquid which has evaporated. Owing to the small size of the cells a large number of them can be placed within a very small space, a property which is extremely useful where a portable battery is required for testing purposes.

TECHNICAL DRAWING.—XXII.

DRAWING FOR MACHINISTS AND ENGINEERS.

PROJECTION AND DEVELOPMENT.

In this plate the projection and development of a cylinder, penetrated by two other cylinders at different angles, are shown.

Fig. 220 is the elevation of the object, of which it is required to project the plan.

Draw a horizontal line in the lower plane, and from A and B of the elevation drop perpendiculars meeting it in A′, B′ (Fig. 221); then the distance between these two points will be the entire *length* of the ground covered by the object.

Now to find the width of the plan, draw the central line or axis in the elevation, C D, and from C and D draw perpendiculars passing through the line A′ B′ in *c* and *d*.

The line *c d* is then the plan of the axis.

At any part of the axis of the elevation describe a circle equal to the true section of the cylinder, and through its centre draw *e f* at right angles to C D.

On each side of *c* and *d* in the plan set off the length of the radius of the circle, *o d′*, *o d″*—viz., *c* C′, *c* C″, and *d* D′, *d* D″.

Draw C′ D′ and C″ D″, which will give the width of the straight part of the cylinder.

Now it must be remembered that the circle drawn at *o* represents the section at *right angles* to the axis, which for the present purpose is supposed to be rotated on *e f*, and this will explain the following process:—

Divide the circle into any number of equal parts in the points *k*, *i*, *d′*, *g*, *m*, etc.; then the length of the line joining the points, as *m n*, which are opposite to each other, will represent the width of the cylinder at that part as it would be seen on looking down upon it.

Therefore, through *g*, *h*, *i*, *j*, *k*, *l*, *m*, *n* draw lines parallel to the axis of the cylinder and cutting the end of the cylinder in *m′ n′*, *g′ h′*, *i′ j′*, and *k′ l′*.

From these points drop perpendiculars passing through the plan, and on them from the central line, A′ B′, set off the lengths of the lines drawn across the circle, measuring from the line *e f*; thus, *g″ h″* and *i″ j″* in the plan will be the same length as the lines *g h* and *i j* in the circle *o*, etc. Through these points the ellipse is to be drawn, which is the horizontal section of the cylinder at this angle, and here seen in plan.

It is scarcely necessary to mention that the end on which

the cylinder rests—viz., A E—will be projected in precisely the same manner, and the same working lines will serve for the one end as well as for the other.

Thus, from the points where the lines drawn through *m*, *n*, *g*, *h*, etc., in the circle *o* cut the line A E, drop perpendiculars, which, being intersected by horizontals drawn from the points correspondingly lettered in the plan, will give the points through which the ellipse of the lower end is to be traced; one-half of this being hidden when looking down upon the object, it is drawn in dots.

It is now required to project the plan of the cylinder, G H I J, which penetrates the original object, and it will at once be will give the ellipse representing the plan of the circular end, H I.

The projection of the upright cylinder, by which the longest one is penetrated, and on which it rests, is obtained in the same manner, and it is believed that the student will be able to work this without instructions, observing that the plan in this case is a circle.

We now proceed to show the method of finding the exact shape of the sections, or surfaces at which the cylinders touch each other at their penetration; and as all are executed on the same principle, it will be sufficient to demonstrate the process on one section—that at O P.

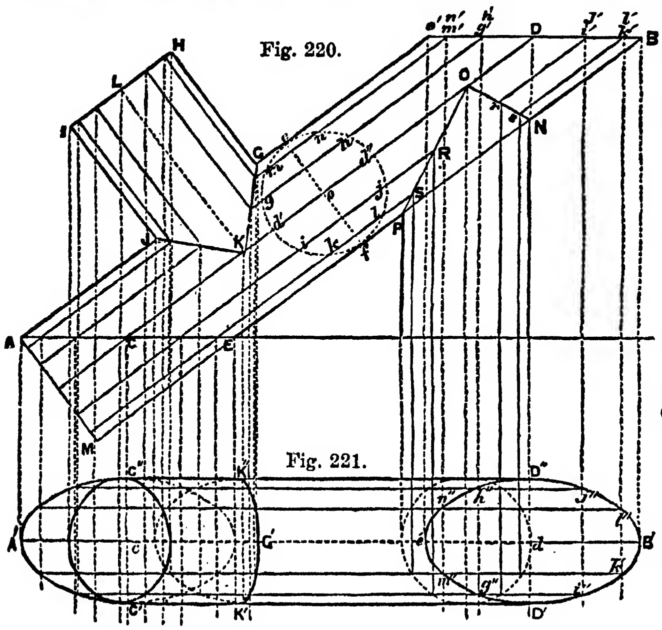


Fig. 220.

Fig. 221.

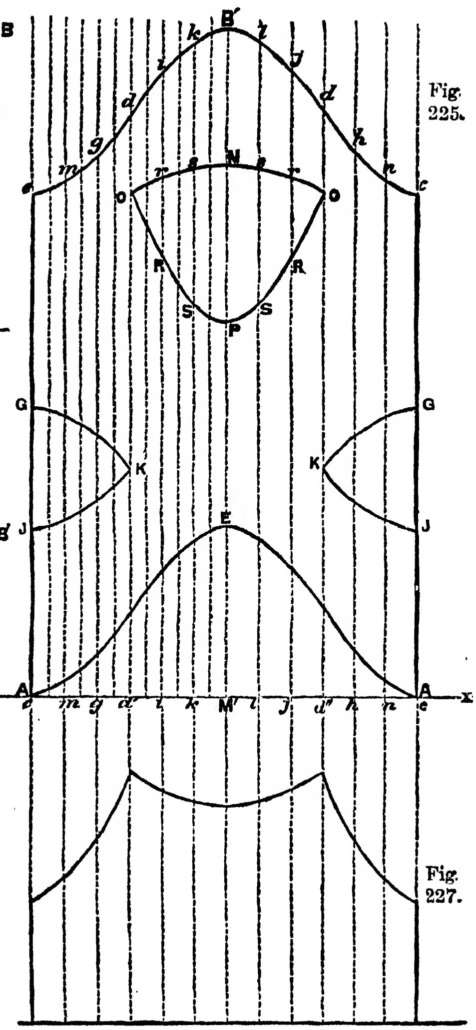


Fig. 225.

Fig. 227.

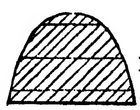


Fig. 224.

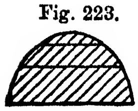


Fig. 223.

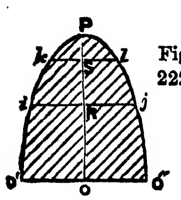


Fig. 222.

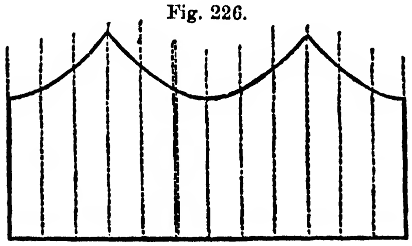


Fig. 226.

seen that the line L K, which is drawn at the widest part of this smaller cylinder, intersects D C at right angles in K; therefore, from K drop a perpendicular which will cut C' D' and C" D" in K' K".

From G drop a perpendicular cutting A' B' in G', and from the points where the lines drawn through *m*, *n* and *g*, *h* cut G K in the elevation, draw perpendiculars intersecting the corresponding horizontals in the plan, thus obtaining the points through which the junction curve, K" G' K', is to be drawn; the portion J K is to be projected in the same manner.

Now, again, from the points where the lines drawn through *m n*, etc., in the elevation cut G K and J K, draw lines parallel to L K, cutting H I in several points, left unlettered to test the knowledge of the student. From these points perpendiculars are to be drawn intersecting the horizontals in the plan, which

Fig. 222.—Draw the horizontal O' O" equal to the diameter of the cylinder. At O draw a perpendicular to P, equal to O P, in Fig. 220, and set off on it the lengths R and S—the distance of the points at which the lines drawn through *i j* and *k l* cut O P—viz., R, S. Draw lines through R and S parallel to O' O" (Fig. 222), and make them equal to *i j* and *k l* in the circle *o* (Fig. 220).

Through O, *i*, *k*, P, *l*, *j*, O" draw the half ellipse, which is the form of the section at O P in the elevation.

Fig. 223 is the section at N O, and Fig. 224 is the section at G K and J K.

Fig. 225.—In order to develop the surface of this cylinder, draw a horizontal line, as X X, and a perpendicular, as M' B'.

Now returning to the elevation, produce the line B E, and draw M A at right angles to it.

It will be seen that this addition completes the lower end of the cylinder, as if that portion were embedded in the ground-plane; thus the real length of the cylinder is proved to be the distance between M and B, and it will be clear that if the cylinder stood on M A, the height of each point in the section would be the length of the perpendiculars drawn from them; but they would be further apart than they appear to be on the elevation, in which they seem to become closer as they recede from the centre line.

Therefore, from M′ (Fig. 225) set off the divisions *k*, *i*, *d′*, *g*, *m*, *e*, and *l*, *j*, *d″*, *h*, *n*, *e*, measured from the section in Fig. 220.

At each of these points erect perpendiculars. If the circle be large it is advisable to divide again, so as to obtain more perpendiculars, as shown on the left side of the figure, since by this means the difference between the arcs and the straight lines represented by the divisions is diminished.

Now from M′, in Fig. 225, mark off the length M B, taken from Fig. 220, and on each of the perpendiculars mark off the lengths of the lines correspondingly lettered in Fig. 220—viz., measuring from A M in Fig. 220, and setting off the distances from the line X X in Fig. 225. Now through *e*, *m*, *g*, *d*, *i*, *k*, B′, *l*, *j*, *d*, *h*, *n*, *e*, draw the curve for the top of the cylinder.

From each of these points set off the *uniform* length, B E, all the lines in the elevation parallel to B E being of the same length. The curve drawn through these points will be the form of the lower end of the cylinder.

It will be seen that the lines of penetration, N O and O P (Fig. 220), cut through the parallel lines through *i*, *j* and *k*, *l* in *r*, *s* and R, S.

Measure the distance of these points from A M, and set them off on the perpendiculars in Fig. 225, as already shown, and the curves formed in joining the points will be the shape of the aperture which would receive the cylinder on which the oblique one rests.

The opening G K J is obtained in the same manner, and is drawn half on each side, the metal or covering of the cylinder being supposed to be cut open on the line *e′* A.

Figs. 226 and 227 are the developments of the smaller cylinders, which, being obtained in the manner just explained, require no further comment.*

MECHANICAL DRAWING (*continued*).

THE TEETH OF WHEELS.

In order to transfer motion or force from one axis to another, wheels furnished with teeth are employed, and although the mathematical calculations connected with the forms, etc., of teeth do not come within the province of these lessons, the method by which those forms are to be drawn is a necessary and important part of our subject.

If two circular plates, A and B (Fig. 228) were placed so that their edges touched each other, and one of them were rotated on its axis, it would communicate motion by "rolling contact" to the other; but, of course, we could never expect very great force from such motion.

Now the transmission of force is one of the conditions of machinery; therefore such means are taken as shall enable the wheels, not only to communicate motion, but power as well.

One moment's reflection will convince the student, that if the edge of a penny be pressed against that of a farthing, whilst the latter is held between the finger and thumb, the farthing will only move round whilst it is being held very loosely, because the edges of both the discs are smooth. If, however, a half-crown and a sixpence be substituted for the former coins, the additional friction caused by the milled edges will allow of the sixpence being moved by the half-crown when held much more tightly than the farthing; in other words, the projections (or *teeth*) on the edges of the discs enable them to overcome greater resistance than if they were smooth.

It is clear, that although A (Fig. 228) would move B when their circumferences touched each other, yet if a weight attached to a cord were wrapped round the axle, as shown in the figure, resistance would be offered, and the edge of A would *slide* against that of B.

Let, however, a pin be inserted at C in A, and another at D in B, and it is easy to understand that as the one presses against the other during rotation, *motion* and *force* will be communicated.

But these pins could not pass each other, because the points of the circles on which they are situated would gradually approach until they absolutely touched each other, as at E. The motion would therefore be stopped altogether, or the pins would be broken off. It is therefore necessary that between the teeth spaces should be cut which shall sink into the edge of the disc, as shown at F and G. Then as the teeth approach each other, the point of the one enters into the space next to the other, and thus the action is continued. The motions, then, of wheels are exactly the same as those of two circles rolling upon each other.

The original circles which roll on each other are called the *pitch-circles*, and when the system consists of a wheel and rack (*a circle rolling on a straight line*), the line on which the circle rolls is called the *pitch-line*.

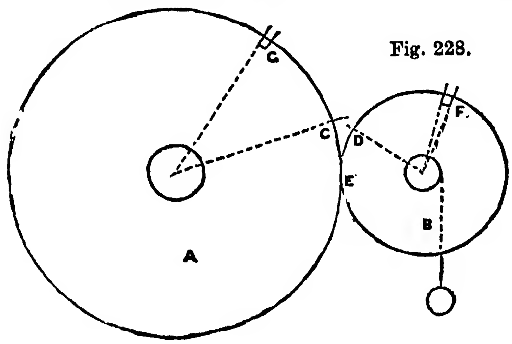
The great effort of the engineer in designing the teeth, is to enable the wheels to move with an accurately uniform motion: the various forms given, and the mode of constructing them, will form the subject of our study.

There are various kinds of wheels: the following are the most important:—

Spur-wheels are such as have their teeth standing out directly from the edge.

When the teeth are made of wood, and inserted separately

Fig. 228.



into the rim, they are termed *cogs*, and the wheel is called a *cog-wheel*—a form much used in mill-work. A sketch of this kind of wheel will be given in a future lesson.

Face-wheels have their cogs or pins placed perpendicularly to the face of the wheel.

Crown-wheels have their teeth standing perpendicular to the rim, as if the teeth had been first cut on a straight strip, which had afterwards been bent round.

Annular-wheels are such as have their teeth cut on the inside of the rim or ring.

Bevel-wheels are portions of cones—the teeth being cut on the slanting surface: they are, in fact, spur-wheels the teeth of which are on the conical side, instead of the edge. They convey motion when the axes are at angles to each other. When the cones are equal, they are called *mitre-wheels*.

It is sometimes convenient that the axes of bevel-wheels should pass close to each other without intersecting; the teeth have then a peculiar form, and the wheels are called *skew-bevels*.

The curves generally used for the form of the teeth are the cycloid, the epicycloid, and the hypocycloid—the construction of which will be fully described in "Practical Geometry applied to Linear Drawing." It will, therefore, only be necessary here to remind the student that the cycloid is traced by any point in a circle whilst rolling along in a *straight line*; that the epicycloid is traced to a point in a circle rolling *against the edge of another circle*; and the hypocycloid is the curve traced by any point in a *circle rolling round the inner side of the circumference of another circle*.

The circle which forms the curve is called the *generating circle*. When the diameter of the generating circle is equal to the radius of the circle in which it rolls, the hypocycloid becomes a straight line: this will be referred to hereafter.

* For elementary instruction as to development of cylinders and their sections, the student is referred to lessons on "Projection."

OPTICAL INSTRUMENTS.—V.

BY SAMUEL HIGHLEY, F.G.S.

SPECTACLES FOR THE PRESBYOPIC (*continued*).

THE following table, drawn up by Donders from carefully recorded statistics, may prove of service to the optician as a guide to what glasses are required at different ages in emmetropia, with normal acuteness of vision, and accommodation for writing and for reading ordinary type :—

Age.	Glasses Required. In Present. E.	Glasses Required. In Original. E.*	Distance of Distinct Vision.	Far Point.	P_2 Near Point.
			Inches.	Inches.	Inches.
48	1-60th	1-60th	14	60	10
50	1-40th	1-40th	14	40	12
55	1-30th	1-28th	14	30	
58	1-22nd	1-20th	13	22	12
60	1-18th	1-16th	13	18	12
62	1-14th	1-12th	13	14	12
65	1-13th	1-10th	12		11
70	1-10th	1-7·5th	10	10	10
75	1-9th	1-6·5th	9	9	9
78	1-8th	1-5·5th		8	8
	1-7th	1-4·5th		7	7

We have said that presbyopia occurs not only in the emmetropic eye (Fig. 6, page 160), but also in the hypermetropic (Fig. 8), and in the myopic (Fig. 10), that is, if we adopt Donders' standard near-point at 8 inches.

Thus, if with the convex glass which neutralises the hypermetropia (that is, renders the hypermetropic eye capable of uniting parallel and divergent rays upon the retina), the near-point lies at 12 inches, the patient is not only hypermetropic, but also presbyopic, and he will require two different pairs of convex spectacles—one pair to enable him to see from 12 inches to infinity, and another stronger pair, which will bring his near-point nearer than 12 inches.

Or should the patient possess a myopia = $\frac{1}{16}$ (his far-point lying at 16 inches from the eye), and we find his near-point lies at 12 inches; then he is not only short-sighted, but long-sighted also. His myopia = $\frac{1}{16}$, his presbyopia (as shown above) = $\frac{1}{24}$.

The opinion of oculists is divided as to the proper time emmetropics should begin to use spectacles. On the one hand, it is asserted that the employment of convex glasses should be deferred as long as possible; and to this prejudice the vanity of human nature is too ready to give support, the adoption of spectacles being in such cases regarded as an outward visible sign of an inward material decay—of the advent of age. But must it not be regarded as folly to unnecessarily weary both eyes and brain, in guessing, with much trouble, at letters, stitches in needlework, etc., which could be seen distinctly by the aid of spectacles?

But, on the other hand, an opposite error of judgment prevails, viz., that, by recommending the early employment of weak spectacles, the power of vision may be preserved; hence such terms as "preservers," "conservative spectacles," in connection with which may be noted the introduction of "amber glasses," "tinted spectacles" (light yellow, pink, or blue glasses), *et hoc genus omne*. In connection with the latter, the following caution may be given—viz., that most persons are ready to employ them, on account of their agreeable, soothing influence; but we must remember that coloured, even but slightly-tinted glasses, withhold from the retina the ordinary stimulus of white light, so that its sensibility is abnormally increased, and thus they create a permanent necessity for their constant use. It need hardly be said that a more than normal sensibility in the retina is an inconvenience, which, moreover, predetermines to disease. The common sense of the question seems to be, that so long as the eye does not err, and remains free from fatigue in the work required of it, its own power is sufficient, and it is inexpedient to seek unnecessary assistance from convex glasses. On the contrary, as soon as the eye begins to feel teased by the every-day work required of it, the aid of the optician, or the advice of the oculist, should be sought.

* This will be referred to under treatment of *Hypermetropia acquisita*.

Another question arises. After commencing the use of spectacles, how often ought the sights to be changed? The answer is: As slowly as possible; for every advance is, as it were, a milestone passed on the road to virtual blindness—that is to say, were the rate of change too rapid, and the person lived to an advanced age, a point might be arrived at when the optician's resources would be exhausted, and then the dimmed sight could no longer be aided, for the deepest lens would have been passed, and found to fail with increasing years.

The proper course is to use the weakest spectacles that will give the desired assistance, only in the evening, and to keep these for day spectacles so soon as stronger glasses are required for evening work; and so with every change, the weaker glasses being used for day, the new and stronger glasses for the evening. Moreover, the weaker glasses should be used for writing, while the stronger are reserved for reading; for the reason that the wearer can see with them at a greater distance, and to avoid the bent position for writing which becomes a custom with the short-sighted—a position injurious to the eyes, as it tends to throw the blood to the head, and so congest them.

And here it may be noted that should a person apply to his optician for an increase in the power of his glasses, at shorter intervals than is usual, and a rapid increase in his presbyopia is really observed, this may be suspected as a premonitory symptom of "glaucoma," especially if a greenish opacity behind the pupil is noticeable: in such case the person cannot be too quickly sent to the ophthalmic surgeon, for the threatened disease is of a formidable nature.

Contrary to what might be expected, persons who are occupied almost the whole day in reading, writing, or other close work —even such as that of watchmaking and engraving—who are obliged to employ a magnifier, or as microscopists, do not essentially injure their eyes, nor does their range of accommodation diminish scarcely, if at all, more rapidly than it does in sailors, agriculturists, and others, who, for the most part, look at distant objects. At least, this holds good with emmetropics, and even those disposed to myopia; though much reading or writing tends to make them more short-sighted, yet such occupations have no influence on their range of accommodation.

But there are morbid conditions which cause the range of accommodation, and sometimes also the amount of ; to diminish more rapidly than usual, such as general debility (the result of exhausting disease), premature old age, and glaucoma previously referred to. In all such cases, the optician should only supply spectacles under the guidance of the ophthalmic surgeon.

In many instances the optician will be called on to adapt glasses to meet the requirements of the calling of his customer. Some occupations, such as minute drawing, engraving, watchwork, minute anatomical dissections, and microscopical mounting, require the constant use of the magnifying glass. In other work the eye, even with normal acuteness of vision, must at least be still accommodated for distances from 4 to 6 inches. In such cases convex glasses become a necessity, to render permanent accommodation for such distances possible. In other cases, the work must be performed at definite distances, such as, in writing in large registers, reading in the pulpit or in the orchestra, in the use of certain musical instruments, etc. It is often desirable to bring the distance of distinct vision to 18 inches, or 2 feet; so weaker glasses are necessary where, in the former cases, stronger ones would be required than would be given for reading or writing. Guided by sound principles and practical experience, the optician soon finds what spectacles meet the special requirements of each case.

THE STEAM-ENGINE.—V.

STEAM-PIPES—THE CYLINDER—PRINCIPLE OF ALTERNATE MOTION—THE PISTON AND ROD—PACKING OF THE PISTON.

HAVING now mastered the mysteries of the boiler and its various appendages, we must turn our attention to the mechanism and construction of the engine itself. This, as we have explained, may be, and often is, entirely separate from the boiler, yet without it the engine is of no use. The boiler may be regarded as the part of the machinery where the power is generated, and the

engine as that portion where this power is brought under control and made to accomplish the ends we desire.

In locomotives and portable engines the two are usually combined, the various parts of the engine being securely fastened to the boiler itself or the framework which supports it; but this is done merely as a matter of convenience. In large manufactories, where much machinery is employed, the boilers are almost universally separate, and often at a distance from the engines to which they supply steam; and this is the most general plan. There are usually several boilers placed close together, and they may be employed either singly or together; so that in case of any one requiring repair, steam may still be generated in the rest, and no stoppage of the machinery is caused.

Several engines are often driven from one set of boilers. In many cases, indeed, a small engine is attached to the machine it is to drive, and is made a part of it, and a small steam-pipe is then connected to it. This is often found to answer better than driving the machine from the ordinary shafting, and has, besides, another advantage—viz., that if flexible steam-piping be employed, the machine may easily be shifted from place to place without altering the connections. In the case of pumps, this is frequently found to be a very great convenience. Cranes, centrifugal drying machines, and various other small machines, are frequently thus fitted with an engine of their own.

It will, however, be much better to defer the consideration of these special engines for the present, and first of all to inquire carefully into the construction and action of the various parts of some simple form of engine; and, having done this, the various modifications introduced will then be far more easily understood.

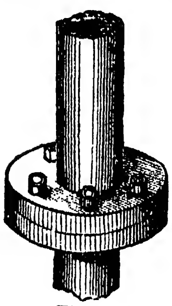


Fig. 21.

We will therefore inquire in this way into the principle of the most common form of engine, such as may frequently be seen in any large factory, and is known as a "low-pressure beam engine."

Various lines of shafting run along the different floors of the building, all of which are set in motion from the engine. All the various machines are then driven from this shafting, pulleys or sheaves being fixed at various intervals along it, over which straps pass to the different driving-pulleys of the machines.

In the boiler we have a continual production of steam at a high pressure, which will find its way into the air as soon as any escape is provided for it. The first thing, then, is to conduct this steam to the engine. For this purpose a pipe starts from inside the boiler, and passes through it and on to the engine. The mouth of this pipe is usually placed in the upper part of the steam-chest, or, failing this, as near the top of the boiler as possible, so as to guard against the fine spray, which is produced by the rapid ebullition, entering the pipe with the steam, and being deposited in it or in the various parts of the engine. Much care is required in arranging for this, as otherwise excessive condensation of water, technically called "priming," will be produced, causing much inconvenience and loss of power.

Wrought-iron piping is usually employed for the passage of the steam, and it should be of sufficient diameter not to impede the passage of the steam, since that would cause a material diminution in the pressure. This piping has to be very carefully made, and tested for strength. At the ends of each piece are flanges with bolt-holes drilled through them, and their faces are turned so as to be nearly true. When two pieces are to be joined together, some hemp packing, well smeared with red lead, is laid spirally on one face, the other is then brought up against it, bolts are passed through the holes, and the nuts are firmly screwed on (Fig. 21). The joint thus produced will last indefinitely, and if carefully made is perfectly steam-tight. Other kinds of packing are sometimes employed in place of hemp and red lead.

When the engine is at any distance from the boilers, and the steam has therefore to travel along many feet of piping, there is a considerable loss of heat by radiation from the pipe. To guard against this it is nearly always packed with straw, or covered with wood, felt, or some other non-conducting material. Very frequently this "lagging" brings up the size of the pipe to that of the face-plates, so that they are hidden, and the pipe appears to be of uniform size throughout. The steam-pipe usually leads direct to the cylinder, and it always has a valve in it near this point, by means of which the steam can be shut off when we wish to stop the engine. Besides this, there is a valve placed just where the pipe leaves the boiler, so as to shut off steam there in case of any injury to the first valve or the pipe; and in addition to those there is usually a "throttle-valve" in the pipe, which is moved by the governor balls, and serves to regulate the supply of steam in accordance with the requirements of the engine, as will be fully shown hereafter.

The amount of force existing in the steam will, by a moment's consideration, be seen to be very great indeed. As already explained, a cubic inch of water when converted into steam occupies at the pressure of the air very nearly a cubic foot—that is, it expands 1,700 times. In doing this, it has to overcome the pressure of the air, and therefore exerts a pressure equivalent to raising a weight of 15 pounds to a height of 1,700 inches. This will be more clearly seen if we imagine our cubic inch of water to be placed at the bottom of a tube of indefinite length, having a sectional area of exactly one inch, and to have above it a piston, fitting the tube air-tight, but supposed to be without weight, and to move without friction (Fig. 22). Now the air presses with a force of 15 pounds on a square inch, and as this is the area of our tube, we may regard the water as pressed upon by a single weight of 15 pounds. Now let the water be gradually converted into steam, the piston will rise till it attains an elevation of 1,700 inches, or 142 feet nearly, all the time resisting the pressure of the air, which is equivalent to lifting a weight of 15 pounds. This, then, is the work accomplished by the evaporation of one cubic inch of water = 15 pounds raised 142 feet, or 142×15, that is 2,130 pounds raised one foot high. To remember this we may express it in the following statement, which can easily be borne in mind:—

Fig. 22.

The force produced by the evaporation of a cubic inch of water is sufficient to raise a weight of nearly one ton to a height of one foot.

Only a small portion of this force is utilised in any engine at present constructed; but we must now see how this portion is utilised in the ordinary forms. Various plans for driving machinery by means of this force have been suggested and tried: some have let the steam, as it issues from a jet, strike against a set of vanes, and thus impart motion to them; others have suggested the employment of a wheel similar in construction to that used in the water turbine; but the only plan that has come into use has been the employment of a cylinder with a piston moving up and down in it.

The cylinder consists of a strong cast-iron tube of large dimensions and of considerable thickness. Its size varies with the power of the engine; but it is usually about half as long again as its diameter. Its interior surface is bored or turned with great care, so as to be perfectly cylindrical and of uniform diameter throughout; it should also be free from flaws. Covers or caps are firmly bolted on to each end, the joints being packed so as to be perfectly steam-tight, and suitable apertures are made near the end to provide for the ingress and egress of the steam. As it has to withstand the pressure of the steam and the jarring of the piston, this cylinder must be firmly and strongly made.

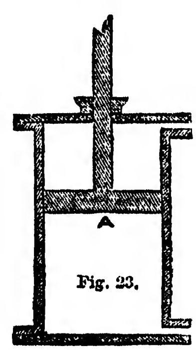


Fig. 23.

Inside this there is a piston which can move up or down, but fits steam-tight. It is likewise composed of metal, and is virtually a disc of considerable thickness firmly attached to the piston-rod, which moves through an opening provided for it in the upper cover. We can now understand, by reference to Fig. 23, the manner in which this piston is driven by the steam.

Let us first of all suppose that the piston is of considerable weight, and is nearly at the bottom of the cylinder, which

is so arranged that it cannot quite rest in contact with it. The steam from the steam-pipe is now allowed to enter the lower end of the cylinder, through the port E. Its pressure at once overcomes the weight of A and the pressure of the air on its upper surface, and raises it to the top of the cylinder, the air which previously occupied that space being driven out through D.

If now the steam be shut off, and the pipe removed, or, simpler still, if a second opening be provided, the weight of the piston will drive out the steam into the air, and force the piston down again to the bottom.

The steam may then be re-admitted, and the piston will be driven up again as before, and in this way an alternating movement of the piston-rod is obtained, which may easily be converted into one of rotation. This, then, is the simple principle of the engine, and, as will at once be seen, the chief difficulty here would be to provide some means for making the lower part of the cylinder communicate alternately with the steam-pipe and with the air. This may, however, be easily accomplished by means of a two-way cock, as shown in Figs. 24 and 25. In each figure C represents the pipe communicating with the lower part of the cylinder, and S the steam-pipe, while A is open to the air. The passage through the plug of the cock is curved, as seen in the section, and when in the position shown in Fig. 24, a direct path is opened for the steam to pass into the cylinder, while all communication with the air is cut off. When the piston reaches the top, the tap is turned one-fourth of a revolution, to the position shown in Fig. 25; the steam is thus cut off, and that already in the cylinder can escape through A into the air.

In this, which is the simplest form of engine, there are many important defects which have subsequently been to a greater or less extent overcome. The pressure of the air, it

Fig. 24.

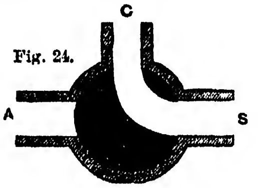
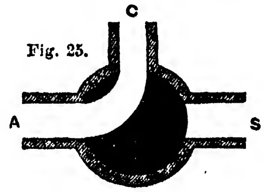


Fig. 25.



will be observed, obstructs materially the upward progress of the piston, since it presses on every square inch of its surface with a pressure of fifteen pounds. It does not, however, aid in driving it down, since when the piston is descending, both sides are equally exposed to its pressure. There is, therefore, in this way a very great loss of power. This is almost entirely avoided when a condenser is used. The steam then, instead of issuing into the air, is allowed to pass into an exhausted vessel, in which it is condensed into water, and a vacuum thereby produced. The pressure of the air then impedes the ascent of the piston as much as before, but, since there is a vacuum in the lower end of the cylinder, it aids the descent in almost the same degree, and thus, on the whole, there is little loss.

Another disadvantage of this form of engine is, that its action is very uneven. The piston is driven by the force of the steam to the upper end of the cylinder, while the return is accomplished merely by its own weight, or any weight with which it may be loaded. In some cases, however, this is not nearly so great a drawback as in others.

In a pumping-engine, for example, the whole strain is when the pump-rods are being raised, their own weight being sufficient to carry them down again. A single-acting engine is, therefore, employed for this purpose; the piston is, however, usually forced from the top to the bottom of the cylinder, the pump-rods being attached to the other end of the beam, so that the water is raised while the piston is descending. In a future paper we shall introduce an illustration of this engine, and enter into the details of its construction.

If we return now to our original cylinder (Fig. 23), we shall easily see that, if by any means we cause the steam to enter alternately at the upper and lower ports—the other port, in either case, being in communication with the air—we can make a double-acting engine, the piston being now driven in each direction, instead of in one only as in the former case. By using a four-way cock this may easily be done, and we shall thus have a model showing the principle of the double-acting engine. The student will from this understand the principle on which the steam-engine acts, and we can therefore turn our attention now to the construction of the piston and piston-rod, and the manner in which the supply of the to either end of the cylinder is regulated.

The piston is usually made either of cast-iron or brass, the latter being preferred, as it is lighter and does not so easily break. Round the edge of the disc a deep groove was formerly turned, which was completely filled with well-lubricated packing. The piston was then made in pieces, and the top disc attached to the rest by screws. By tightening these the packing was compressed and forced against the sides of the cylinder, so that the steam could not pass; at the same time the undue wear of the piston or cylinder was prevented. Fig. 26 will explain this mode of construction.

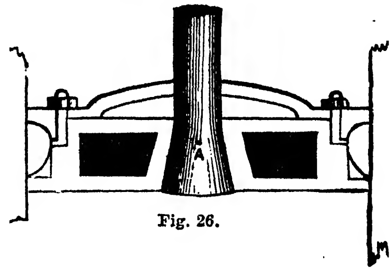


Fig. 26.

In practice, however, it is found that pistons packed in this way are far from durable, and much inconvenience is often caused by their getting out of order. They have, therefore, almost entirely given place to those which maintain steam-tight contact without packing, and are known as metallic pistons. In these there is a very great variety in the mode of construction, though the principle on which they all act is essentially the same.

The groove round the piston, instead of being curved, is rectangular in section, and contains, in place of the hemp, two or more packing rings, which are usually made of brass. These are flat rings, having the same external diameter as the piston; they are made in several segments, the ends sometimes being tongued and grooved to keep them in position. The joints in each ring are so arranged as to be intermediate to those in the others. Strong steel springs are then placed in the piston, in such a way as constantly to force the segments of those discs outwards, and the result is that they press against the interior of the cylinder, and become gradually worn, so as exactly to fit it, and as the pressure is uniform and the surfaces well lubricated, there is not much wear or friction. In Fig. 27 we have a cross-section of a piston of this kind. There are two packing rings, each of which is divided into two segments, as shown. Inside these is a thin steel ring, and then come the springs, of which there are five. These are made of strong steel, and may be tightened by the screws, which are seen behind them.

Pistons packed in this manner are found to last a long time without showing signs of wear, and may usually be easily repaired. The points required in any form of packing are perfect contact at all parts, so that no steam may pass by, and, on the other hand, not so strong a pressure against the sides as needlessly to increase the friction; and this medium may easily be obtained by properly adjusting the screws.

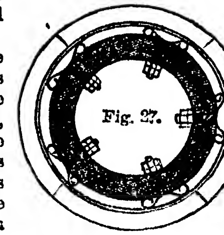


Fig. 27.

The piston-rod is frequently made with a flat disc firmly welded to its end. The piston then has a hole drilled through it to admit the rod, and its base is countersunk, to make room for the disc. When it is slipped on the rod, and is in its place, a pin is put through the piston edgeways, and holds both firmly together.

In other forms the lower end of the rod is made somewhat larger and tapering, so that when in its place it fits firmly, and, as in the former case, is kept from slipping by a pin driven through both, as shown at A in Fig. 26.

In locomotive pistons, and other cases, where the diameter is comparatively small, the piston and its rod are not unfrequently made in one piece, and all fear of their becoming loosened by the alternating pressure is thus avoided.

OPTICAL INSTRUMENTS.—VI.

BY SAMUEL HIGHLEY, F.G.S., ETC.

SPECTACLES FOR THE MYOPIC.

In selecting spectacles for the myopic, great care is necessary, as, on account of the morbidly distended condition of the eyeball, and of the tendency to get worse, unsuitable glasses might prove very dangerous. In some cases the myopia is so slight, that persons are not aware (as previously stated) that they are really short-sighted. On directing them to look at the distance-test, a decided improvement in their sight is admitted, on their trying slight concave glasses of 60 or 50 inches focus.

The detection of myopia, as a rule, is not difficult. It might be confounded with that weakness of sight termed amblyopia, for amblyopic persons, in order to obtain larger retinal images, hold small objects very near to the eye. How can we distinguish whether the patient is myopic or amblyopic? If he cannot (like short-sighted persons) distinguish very small objects, or if concave glasses, through diminishing the size of the retinal image too much, impair rather than improve his sight; and, further, if he can see test type No. II. at five inches' distance, and can see type double that size at twice that distance; then he is *amblyopic*, for in this case the retinal images increase in proportion to the size of the print, and all the weak-sighted require is large retinal images; whereas in myopia it is different, for although the short-sighted see large type further than small, the proportion between the distance and size of the print is far less. If, with a suitable concave lens, a person complaining of short-sightedness can read type of the size shown in the words "number eighteen" in this page, and the words "number sixteen of Jäger," at the same distance as the normal eye—viz., 20 feet—then he is simply *myopic*. If, however, with the most carefully selected glasses he can only read the word "Trent" in this page at the distance of 20 feet, then it is a case of *myopia complicated with amblyopia*, and the less the concave glasses correct, the greater is the degree of co-existing amblyopia, and *vice versâ*.

We must be careful not to jump to the conclusion, that because a person cannot see well at a distance, he must of necessity be myopic; for he may be hypermetropic, in which case convex, and not concave lenses will be required to render distant objects clearly discernible.

In extreme cases of myopia, due to lengthening of the eyeball, *sclerotico-choroiditis posterior* is almost always present, and, according to Von Groefe, if the far-point lies nearer than 5 inches from the eye (the myopia being greater than $\frac{1}{5}$), then *sclerotico-choroiditis posterior* is present, and this dangerous complication requires medical treatment.

number sixteen of Jäger

Trent

number eighteen

In determining the range of accommodation in the myopic eye by Von Groefe's optometer, as previously described, we found in the case stated that the amount of

Now, what glasses would be required to enable the patient to see distant objects? By the 6-inch convex of the optometer we have changed his eye into a very myopic one—in fact, into a myopia of $\frac{1}{5}$; for we should have to place a concave of 5 inches focus before the convex of 6 inches focus to enable it to see a distant object, for this concave lens would render parallel rays as divergent as if they came from 5 inches distance. In order to find the proper concave glass for distance, we deduct concave 5 from convex 6—

$$\frac{1}{6} - \frac{1}{5} = -\frac{1}{30}.$$

Hence the suitable concave glass will be No. 30.

We have thus theoretically found the proper glass; but, on account of the convergence of the optic axes preventing the eyes from accommodating themselves for the far-point (only attainable when we look at distant objects with parallel optic axes), we should probably find in practice that this would prove too strong; for it is a rule that we should give the weakest concave spectacles with which the patient can see clearly and distinctly at a distance, so that he may only make use of a minimum of his power of accommodation, and not have to strain it unduly when observing near objects; for we must remember that he will but seldom have to look for any length of time at a distance, but at near and distant objects alternately. We therefore let him look at the distance-test at 20 ft. distance, and find that he can distinguish it perfectly. We now alternately place very weak concave and convex glasses before the spectacles, and note their effect. If the convex improves his vision, the spectacles theoretically selected are too strong, and we must give glasses of lower number. Should the concave improve vision, the selected glasses are too weak. But if neither convex nor concave effect any improvement, the spectacles that theory indicated suit exactly.

By thus assisting myopes in seeing distant objects we change their eyes into normal ones, for we enable them to bring parallel rays to a focus upon the retina (see D, Fig. 2, page 111). We can also advantageously assist the myopic in seeing things at a short distance, such as reading a sermon, lecture, music, etc., at a few feet distance: as, for instance, a person wishing to see music, while playing on a musical instrument, say at 2 feet distance. Say, for objects at an infinite distance he is using concave spectacles of 12 inches focus. As his myopia equals about $\frac{1}{12}$, then—

12 24 24

Hence concave 24 will enable him to read music at 2 feet distance. It is, however, a much debated question whether short-sighted persons should be allowed to wear spectacles for reading, writing, etc.; but Donders, one of the greatest authorities on the treatment of defective vision by means of spectacles, considers on physiological and pathological grounds that their use is advisable, except under circumstances presently to be named—that their employment is to be strongly recommended. In the first instance it is advisable to give the patient weaker glasses for reading than for distant objects; but if his accommodation be good, it is better, at a later period, to give him spectacles that will completely neutralise his myopia. In the same way, as in the previous case, we have to determine what glasses will meet the requirements of a short-sighted person who wishes to read at a distance of 12 inches. If his myopia $= \frac{1}{6}$, then—

$$-\frac{1}{6} + \frac{1}{12} = -\frac{1}{12};$$

and we give him No. 12 concaves. For the reason previously given, somewhat weaker glasses are desirable.

We should warn such patients against bringing a book close to the eyes, on feeling fatigued from reading. Instead of putting it down, they bring it nearer to the eyes, in order to obtain greater retinal images, and thus strain and tax their power of accommodation too much; and if this is made a practice, it will increase their short-sightedness. Again, the same person should be supplied with weaker glasses for writing, if there be a tendency to congestion of the head, so that the injurious results of a stooping position may be avoided.

When a myopic person complains of fatigue, and that after reading without glasses for a short time the letters become confused, blurred, and appear to run into one another, with pain in and around the orbit (*Asthenopia*—see Diplopia, page 160), then the use of suitable concaves for near objects is indicated. This kind of weakness of sight is especially felt after reading, writing, etc., in a gloomy place or by artificial light; and to ease the fatigue, the person so affected involuntarily rubs his hands over his forehead and eyelids. After a few minutes' rest he once more sees distinctly, but the same annoyance again occurs, only more rapidly than before. The longer the rest given, the longer can work be continued. As a rule, however, it will (according to the experience of Donders) be found that hypermetropia is at the bottom of this affection, and then convex (not concave) lenses must be employed in the ultimate cure. Asthenopia proceeds from fatigue of the muscular system of accommodation.

Myopes should further be warned against anything that tends to produce strong convergence, or writing, or making rectilinear drawings on a horizontal surface, to which end a high and greatly inclined desk should be used; and they should be advised to read with the book in the hand. Emmetropic and hypermetropic do not suffer injury as quickly as myopic eyes from the use of unsuitable glasses. It is better to use glasses that are rather too weak, or no glasses, than such as are too strong, for strong glasses make hypermetropic eyes myopic, and myopic eyes hypermetropic. As a rule, it is much less injurious to produce a certain degree of myopia than of hypermetropia, as in the latter case much is required of the accommodative power: so in myopia we must beware of glasses that are too strong; in hypermetropia, those that are too weak. But we must recollect that every rule has its exceptions, and all the circumstances connected with each particular case, which can exercise an influence on the choice of spectacles, must be duly considered.

Myopia is most prevalent in civilised countries, and, as a rule, in their most cultivated ranks; and while, on the one hand, it is often hereditary, on the other, its foundation is too often laid in schools—more particularly boarding-schools, where by bad lights the pupils read bad print in the evening, or write with pale ink—and so developed in early life. The causes which give rise to myopia are still more favourable to its further development. A near-sighted eye is not a sound eye; its defect is not dependent upon a simple anomaly of refraction, but upon anatomical and pathological causes, which may be progressive in character, and so constitute a true disease of the eye. The higher the degree of the myopia, the less is it likely to remain stationary. In youth almost every myopia is progressive, and is then often accompanied with symptoms of irritation. This is the critical period of the myopic eye. If the myopia does not increase too much, it may become *stationary*, and may even decrease in advanced age; if developed in a high degree, it is subsequently difficult to set bounds to it—it may become *temporarily progressive* or *permanently progressive*. Every progressive myopia is threatening with respect to the future; so that by the age of fifty or sixty, if not much earlier, the power of vision may irrevocably be lost, either through separation of the retina from the choroid, from effusion of blood, or from atrophy and degeneration of the yellow spot. On the advent of myopia in youth, all promoting causes should be carefully avoided, and its rate of progress carefully watched by the oculist.

SPECTACLES FOR THE HYPERMETROPIC.

In myopia, through the state of refraction being too great, or the optic axis being too long (see Fig. 10, page 160), parallel rays are brought to a focus *before* the retina when the eye is in a state of rest; in hypermetropia we have just the reverse of this (see Fig. 8, page 160), and through the refractive power being too low, parallel rays are brought to a focus *behind* the retina, which defect we correct by means of a concave lens suited to the degree of hypermetropia, so as to give the slightly divergent, almost parallel rays, emanating from distant objects, a convergent direction, and bring them to a focus *on* the retina.

In some cases stronger spectacles may be required for near objects also. We need not feel surprise that hypermetropics are often not aware that they see distant objects worse than other people, whereas they would soon discover any deficiency of sight that would affect their capacity in reading and writing. A hypermetropic patient usually complains that after he has been reading or writing for some time the letters become ill-defined, and appear to run into each other, while at a distance, he says, he can see perfectly. The other usual indications of this defect have been previously given. All hypermetropics with a fair amount of accommodation habitually expend a portion of this, to compensate more or less for the deficient refractive power of the eye. The function of accommodation, which by normal eyes is only employed for near objects, is thus by hypermetropic eyes partially, or even nearly exclusively, used for distant ones, which accounts for such persons frequently being unaware of this defect, as previously stated. The proper corrective convex glass can only be found by trial on the distance-test.

We may thus determine the *manifest*, and then by degrees ascertain and correct the *latent* hypermetropia; but as the most efficient method of determining this is by completely paralysing the power of voluntary accommodation by the application of a strong solution of atropine, it is palpable that this defect, when once diagnosed, must pass out of the hands of the optician into those of the ophthalmic surgeon. The patient's power of neutralising his hypermetropia being thus destroyed, his vision will be found to be materially deteriorated, but may again be restored by a convex glass of higher power than that required previous to the paralysis of accommodation.

SPECTACLES FOR EYES OF DIFFERENT FOCI.

As a rule, there is, in all respects, great symmetry between the right and the left eye; but occasionally there is to be found a great difference between the refractive power of the two eyes. We should, therefore, always test each eye separately as to its acuteness of vision, range of accommodation, and state of refraction. All imaginable combinations of refraction occur: with emmetropia in one eye there may be myopia or hypermetropia in the other; hypermetropia or myopia may occur in very different degrees in the two eyes; or the one eye may be myopic, the other hypermetropic. When astigmatism occurs in one eye only, as a rule it will be found that in other respects harmony of refraction exists on both sides; that is, with hypermetropia on one side, the astigmatism in the other will be hypermetropic; with myopia in the right, there will be myopic astigmatism in the left; with emmetropia, the astigmatism is mixed. With difference of refraction we may find binocular vision—vision with each of the eyes alternately—or constant exclusion of the one eye.

When binocular vision is present, at any distance, our aim must be to maintain this, and, if possible, to extend it over a

greater region. In the choice of glasses, where a difference of refraction between the two eyes exists, we allow the eye with least acute vision to remain subordinate to the stronger one, for which we supply the weaker glass, should it be advisable to give lenses of different foci.

It is a popular belief that when two eyes differ, as a matter of course glasses of different foci must be necessary; but in practice this by no means follows, for it is only when extreme difference between the refractive power of two eyes exists that such a course is advisable. When there is only a moderate amount of difference between the refractive power of two eyes, we may give similar glasses for both eyes; and as the relation between the two eyes, to which the person has grown accustomed, remains unchanged, he is satisfied. If we adopted the opposite course, though we make the range of accommodation for both eyes more equal, the magnitude of the images in each would be different, and the result unsatisfactory.

With hypermetropes, when there is imperfect acuteness of vision, it may be advantageous to produce, by means of glasses of different foci, nearly accurate images on the two retinas, by whose co-operation the power of distinguishing is thus, in many instances, really increased.

In rare cases, when the difference between the two eyes is great, and binocular vision is absent, the person may believe himself blind in one eye, especially if that eye be so very short-sighted that objects must be brought unnaturally near to it before they can be recognised—so close, indeed, that the fact of its *not* being deficient in vision may only be discovered when accidentally some object has been brought close to that eye. In such cases, while one eye may require a lens of 20 inches focus, the other may only be suited with a concave of 2 inches. The most suitable glasses must be determined by careful trial.

ASTIGMATISM.

In astigmatism the refractive power of the eye differs in different meridians of the cornea. It is a defect that is not remediable by the ordinary spherical lenses, but by segments of cylinders, which refract only transversely to their axes. This defect is usually tested for by means of lines ruled at different inclinations to each other, such as are given in Snellen's test types, and noting which of such lines are recognised simultaneously; or by the binocular method of M. Javal, whose test-plates consist of two similar circles, one being divided by radii corresponding to the hours on a watch-face, with intermediate shorter radii corresponding to the half-hours; the other being marked with the hour numbers corresponding to the longer radii of its fellow. These are placed so that their centres correspond to the distance between the pupils of the eyes, and are viewed through two lenses, say of 3 inches foci. This test-plate is withdrawn gradually, till all the lines become dim and disappear, excepting one in each disc. Then, beginning with the lowest power, a set of *cylindrical concaves* are brought before the eyes one after the other, with their axes perpendicular to the radius that has remained discernible, till the glass is found which makes all the radii equally black. The meridian of astigmatism, together with the number and position of the correcting glass, is thus determined.

The circles cannot be discerned unless the visual lines are parallel and the head straight. The relative position of the visual lines being a fixed one, this sufficiently guards against any change of accommodation. The patient may state what line he really sees by aid of the hour numbers, as these are not seen by the same eye that notes the radii. This also affords a constant test of binocular vision.

Astigmatism may also be tested by Stokes's "astigmatic lens." This consists of two cylindrical lenses, the one plano-convex l of $\frac{1}{10}$; the other plano-concave $l' - \frac{1}{10}$. The first is fastened into a broad metal ring, the second into a ring that works within the other, to allow of these lenses rotating axially past each other, with their plane surfaces face to face. The outer ring is graduated, and an index-point is engraved on the edge of the inner ring. When the index points to zero or 180°, the axes of the two cylindrical lenses are parallel, and the combination equals a concavo-convex cylindrical lens, with equal radius of curvature of the two planes, whose action is about $= 0$. If the index points to 90° or 270°, the axes of the cylindrical lenses stand perpendicular to one another, and the system has its maximum of astigmatic action, so that by rotating from 0 to 90° the astigmatism ascends from 0 to $\frac{1}{5}$. To save calculation, different degrees of astigmatism are given directly upon the engraved scale. The instrument is set to the degree of astigmatism suspected in the patient, and it is then rotated before the eye while it is fixed upon the distance-test. If improvement be observed in a particular position, the action of the instrument may be increased or diminished until the maximum of distinctness is obtained. The absolute correction of astigmatism indicated by this instrument requires great care, and pertains to the domain of the ophthalmic surgeon rather than to that of the optician, who, however, must carry out the optical remedy the surgeon prescribes for the determined degree of astigmatism.

BUILDING CONSTRUCTION.—XII.

JOINTS IN TIMBER (*continued*).

ANOTHER excellent method of joining beams of timber is that often adopted by ship-carpenters, called "fishing" the beam; and this is used, not only in original construction, but constantly in repairs.

This system consists in placing the two beams end to end, and clasping them between two similar pieces, then either bolting or strapping all three together. In Fig. 91 both these methods are shown. If strapping be adopted, it will be necessary to *scarf* the side pieces to the middle pieces, to prevent any chance of the middle pieces being drawn out. Scarfing timber will be presently spoken of.

This system was used by M. Perronet for the tiebeams, or stretchers, by which he connected the opposite feet of a centre on which an arch was being built, and which, giving way under the load, had pushed aside one of the piers above four inches. Six of such beams not only withstood a strain of 1,800 tons, but by wedging behind them, he brought the feet of the truss 2¼ inches nearer together.

These stretchers were 14 inches by 11, of sound oak, and could have withstood three times that strain. M. Perronet, however, fearing that the great length of the bolts employed to connect the beams of these stretchers would expose them to the risk of bending, scarfed the two side pieces into the middle piece. The scarfing was of the triangular kind, called "Trait de Jupiter" (which will be described in connection with Fig. 98), each "jag" being only 1 inch deep, whilst the faces were 2 feet long, and the bolts passed through close to the angles.

Of course, the methods here described are open to the objection that they increase the width of the beam at the juncture, and that they have a clumsy appearance. This must be admitted; but it is equally certain that they are the strongest systems, and should in every case be used where absolute stability is of more importance than the appearance.

The method of joining next in simplicity is that called "scarfing," which may be of the rectangular or oblique kind. The former is shown in Fig. 92. It consists in "halving" the pieces on to each other, and bolting them together.

Now it will be clear that, when bolted together, the wood will only be *half* as strong as it was before being cut, as half its thickness has been cut away, and therefore the widths $a\ b$ and $c\ d$ represent all the strength remaining in the beam; and even this is injured by the bolt-holes, as already referred to. This is in some degree remedied by affixing iron plates at A and B. But although the beam thus formed might be available for columns, or other vertical purposes, it will be seen that if exposed to cross strain it is liable to give way; for the iron plates, being of but small section, are liable to bend under the weight, whilst the bolts, too, might bend or tear out; and against any forces which might tend to draw the pieces apart no greater resistance is offered.

The author therefore proposes—1. That the parts which are to be halved together should be left several inches longer than required for the mere joint, the surplus portion of each to be formed into a dovetail, to be sunk into the thick part of the other, as at A (Fig. 93). If this is done at both ends, a great protection against the parts being drawn asunder is provided.

2. That instead of bolts, coupling-boxes be employed at each end to cover the joints, as at B these boxes to consist of a bottom and sides, the latter having flanges to which the top is bolted. This will give perfect strength to that which was previously the weakest part. Two or three bands around the

middle part will complete the joining, and these may be slightly countersunk into the *sides* of beams, by which means the parts will be still more surely prevented sliding over each other, whilst they will not be materially injured by the small quantity of wood taken away in that part.

By this system the size of the beam is only increased by the mere thickness of the iron-work, which may be easily covered by a cornice or other joiner's work, should the situation require it.

Fig. 94 is an example of the oblique system of scarfing, and here again it will be seen that, if considered as two pieces of wood joined, it has as a tie but half the strength of an entire piece, supposing that the bolts, which are the only connections, are fast in their holes. The ends of this scarf require strengthening by plates, and a bolt is required through the middle of the

Fig. 96 differs from Fig. 95 only in having three keys. The principle and longitudinal strength are the same. The long scarf of Fig. 96 tightened by three keys enables it to resist a bending much better.

None of these scarfed tie-beams can have more than one-third of the strength of an entire piece, unless with the assistance of iron plates; for if the key be made thinner than one-third it will have less than one-third of the fibres to pull by.

Fig. 98 is the elevation, and Fig. 99 the plan of the French scarf before alluded to, called "Trait de Jupiter," which differs from the method shown in Fig. 97 only in the key being placed at right angles to the slanting line of the scarf, instead of parallel to the line of the beam, as in Fig. 97. The advantage of this method is supposed to be that, when the key in Fig. 97

Fig. 100.

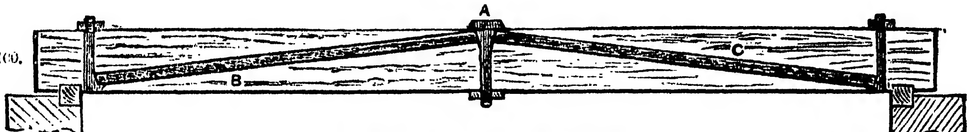


Fig. 101.

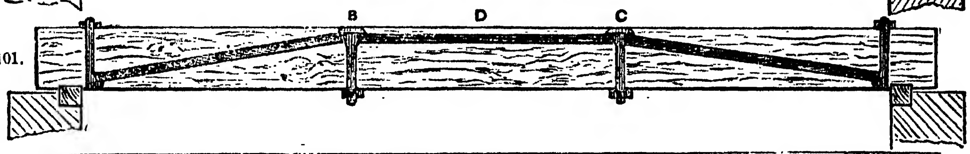


Fig. 103.

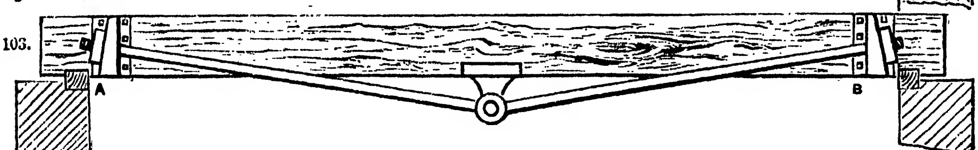


Fig. 91.

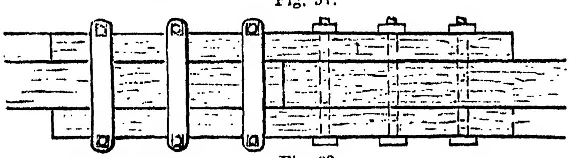


Fig. 92.

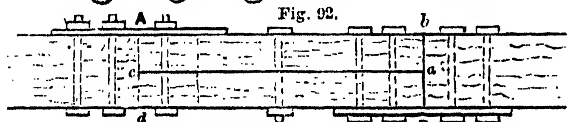


Fig. 93.

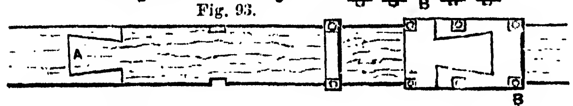


Fig. 94.

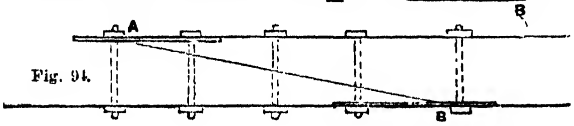


Fig. 95.

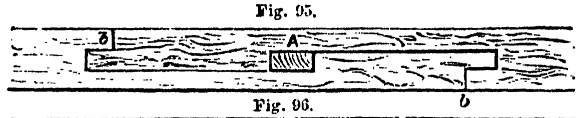


Fig. 96.

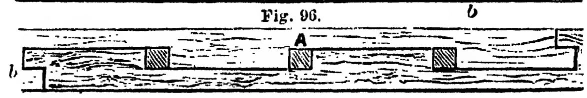
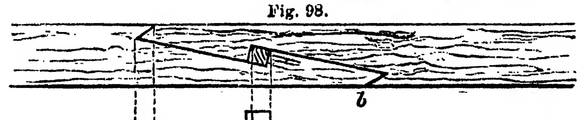


Fig. 97.

Fig. 98.



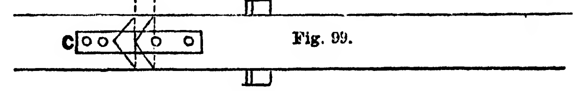


Fig. 99.

scarf. This form of scarf is not adapted for the office of a pillar, because the pieces, by sliding on each other, are apt to splinter off the tongue which confines their ends at A and B.

Figs. 95, 96, 97, and 98 exhibit forms of scarfing which are very generally approved, for either ties or posts. The keys represented at A in each are not absolutely necessary, for the pieces might simply meet square at those points. This form without the key needs no bolts, though they strengthen it to some extent, due allowance being made for the division of the fibres before alluded to; but if worked very true and close, and with square abutments, will hold together, and will resist bending in any direction.

But the key is a great and ingenious improvement, and will force the parts together with perfect tightness; care being taken not to produce constant internal strain on the parts by overdriving the key. The forms of Figs. 95 and 96 are by far the best, because the tongue of Fig. 97 (*a*) is so much more easily splintered off by the strain or by the key than the square wood at *b* in the other two figures.

is driven in, it is liable to split off the piece B, as the force acts in the direction of the fibre; whilst in Fig. 98 the pressure of the key tends rather to press the fibres together than to separate them. But, on the other hand, it seems evident that as the object of the key is to push the parts *away* from the centre, so as to force them tightly against the tongue *b*, the stress coming in the slanting direction, shown at *b*, is by far more likely to splinter the tongue off than when coming in the parallel direction shown at *a* in Fig. 97. Both the French and the English methods are sometimes worked with several keys, and in both the ends of the beams are generally cut to a sally, as shown in the plan (Fig. 99), which prevents the beam bending in a side direction; and this may be further strengthened by the addition of an iron plate, shown at C.

When girders are extended beyond a certain length, they are liable to bend under their own weight. They thus require support, which it is not always possible to give by means of columns or posts. It therefore becomes necessary that the strengthening should be independent of any other support than

that which can be connected to, or contained by, the girder itself. This method is called "trussing." On this subject the writer takes the authority of Mr. Peter Nicholson, who says, "An excellent method to prevent the sagging (or drooping) without the assistance of uprights from the ground or floor below, is to make the beam in two equal lengths, and *insert* a truss, so that when the two pieces are bolted together the truss may be included between them, they forming its tie."

To prevent any bad effects from shrinking, the truss-posts are generally constructed of iron, screwed and nutted at the ends; and to give a firmer abutment the braces are let in with grooves into the sides of each flitch. The abutments at the ends are also made of iron, and either screwed and nutted at each of the ends, and bolted through the thickness of both pieces, with a broad part in the middle that the braces may abut upon the whole dimensions of their section; or the abutments are made in the form of an inverted wedge at the bottom, and rise cylindrically to the top, where they are screwed and nutted. These modes may either be constructed with one king-bolt in the middle (Fig. 100, A), or with a truss-bolt at one-third of the length from each end (Fig. 101, B and C). When there are two such bolts, they include a straining-place, D, in the middle.

It is obvious that the higher the girder the less will the parts be affected by the stress, and consequently there will be the less risk of their giving way under heavy weights, or through long bearings.

Mr. Nicholson says that the rods inserted may be "either of oak, or of cast or wrought iron. The latter material is, however, very seldom used." As this statement does not, however, give any reasons for the employment of either wrought or cast iron, a few observations on this subject are deemed necessary, especially as the immense improvements in the manufacture of iron have caused it to be so much more generally used than formerly, especially as the beams just described are almost entirely superseded by rolled or cast-iron girders.

It is necessary to the present purpose to state, however briefly, that cast iron is *crystalline* in its structure (that is, it is formed of separate particles which have settled into their position whilst the molten metal was cooling); whilst wrought iron is *fibrous* (that is, the particles have been, whilst in a soft condition caused by heat, hammered or rolled together, so that they are of a *long* instead of a *crystalline* form, and their adhesion is thus increased). Malleable iron is therefore able to bear longitudinal strain (that is, the force which would tend to pull the ends apart) better than cast iron; whilst the latter is best adapted to bear vertical pressure, as in a column, without bending or giving way. In brief, cast iron bears *compression*, and malleable iron *tension*; and, to speak familiarly, if the student wishes to know under what circumstances cast or wrought iron ought to be employed, let him ask the question, "Could a *rope* be used?" Now if any weight had to be supported from *below*, it is clear that a rope could *not* be used, and hence columns to bear a roof would be made of cast iron; but when the two feet, A, B (Fig. 102), of the iron rafters of a railway station have to be *tied* together, so as to prevent their spreading out, a rope would (though, of course, not permanently) answer the purpose, and therefore malleable iron would be best adapted. For it is clear that the weight of the roof would have the tendency to push the ends A and B outward, and that, if cast iron were employed, it would be in a state of tension which it is not calculated to bear; wrought iron is therefore best calculated to resist this strain. The rafters C and D, meeting in E, butt against each other, and as the weight of the roof is acting as *pressure*, the rafters are under a transverse stress as well as under a thrust, and here, too, iron would be used. From the shoe in which they meet, and which acts as the keystone of an arch, a rod (E F) can be suspended to bear up the tie-rod A B. Here, again, a *rope* would do; so that this rod must be of malleable iron. The point F being thus firmly held up, may be used as an abutment for "struts," F H and F G, and as these would have to bear the *pressure* of the roof, cast iron would be used: whilst from G and H rods of wrought iron might again be employed to draw up the tie-rod at I and J.

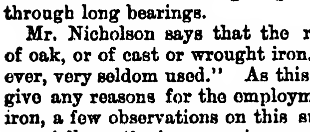


Fig. 102.

Returning now to Fig. 100, it will be evident that the pressure of the beam will be at A, and that the weight at that point would have the tendency to press *downward*. The trusses B and C therefore act as an arch, of which the king-bolt, A, acts as the keystone. The trusses B and C are therefore under *compression*, and cast iron or pieces of oak may be used.

The same remarks apply to the form of truss applied in Fig. 101, where it will be seen there is, as it were, an *arch* formed *within* the girder.

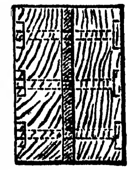


Fig. 104.

Where, however, it is not absolutely required that the trussing should be *within* the girder, far greater strength may be given by adopting the system the simplest form of which is given in Fig. 103. Here the weight of the beam is *suspended from its ends*, at which cast-iron shoes are placed, through which tension rods are bolted. These act on an iron support in the middle of the length, and as the nuts are screwed up at A and B, the tendency is evidently to raise the central casting, and so afford support to the beam. Girders of this form are used to support floors of upper rooms of warehouses, etc., or in schools where, for instance, the girls' department is over that for the boys; also in the now generally adopted system of scaffolding where travelling cranes traverse the work in progress. In such cases where the girders on which the trams are placed for the cranes are of great length, two supports, united by tension rods, are used.

Fig. 104 shows a section of a girder built up of wood and iron, and is called a *flitch* girder. An iron plate is inserted between the two planks, and iron bolts pass through all three; this is found convenient for the architraves of shop fronts, from the convenience with which the casing, cornice, etc., can be attached to it. Beams of this kind also are now almost wholly superseded by rolled or cast-iron girders.

CHEMISTRY APPLIED TO THE ARTS.—VIII.

BY GEORGE GLADSTONE, F.C.S.

SOAP-BOILING.

SOAP is a term applied to various compounds, but it is only with those included under its more familiar acceptation that it is proposed to deal in this article. Such soaps are formed by the action of soda or potash upon fats or oils. Both animal and vegetable oils will serve the purpose of the soap-boiler, though some of them possess peculiar properties which render them specially suitable for certain purposes.

It will be convenient to divide them into three classes—the hard, the soft, and the marine soaps.

The first of these includes a great variety, from the common yellow up to the fancy toilet soaps.

The alkali used in making hard soaps is soda, and it must be in its caustic state. If the hydrate of soda, described in the previous article, be used, the alkali is already in the condition required; but if it be supplied in the form of the neutral carbonate, the soap-boiler has to make it caustic by digesting it with lime.

The fats or oils which may be used are very various. Tallow, olive, palm, and cocoa-nut oils are all extensively used. In addition to these natural oils, oleic acid deserves mention as a waste product of the candle manufactories, but which is of value to the soap-boiler. Rosin is also an important constituent of the yellow soaps. All these, with the exception of the last, which has an altogether different chemical composition, contain stearic or margaric acids, and the hardness of the soap produced is greatly dependent upon the proportion of these acids. The firmness of a soap is a matter of some importance, as one deficient in that respect is more wasteful.

Another important ingredient in soap, especially to the manufacturer, is water. As a mere matter of profit, of course, it is his object to make it take up as much as possible; but though a certain quantity be necessary, it is not wise to push the dilution too far, as the reputation of the maker would thereby suffer. A really firm and apparently good soap can be made, nearly three-fourths of which shall consist of water; but the consumer would very soon find out that its cleansing power was very small, and would not be likely to lay in a

second stock of it. The hard soaps generally contain from 15 to 30 per cent. of water.

The first step in the process of making soap is to boil the fat or oil with caustic lye in large caldrons. These are generally made of iron, and in the best establishments they are heated by steam, being at once more economical and more easily regulated. The steam-pipes are sometimes so arranged that the heat may either be applied externally, or that the steam itself may be forced through the contents of the caldron, in which latter case it not only fulfils its function of heating, but also stirs up the ingredients in a most effectual manner. The boiling-pans are generally made large enough to hold twenty-five to thirty tons of soap at a time.

The fat and alkali are thus boiled together until no grease is any longer seen floating on the surface, but the two have combined together and formed a milky kind of liquid of a neutral character, the acid of the fat having counterbalanced the alkali of the lye. According as the solution is acid or otherwise, more or less of the other ingredient is added, until the cauldron is nearly full, and the proper proportions have been nicely adjusted. Common salt is then thrown in, which readily combines with the water, but not with soap—as any one who has tried to wash in sea-water with common soap will know—the result being that the soap separates in curds, which float upon the surface of the saline liquid, the residue going by the name of *spent lyes*.

The spent lyes being drawn off, the saponaceous matter is again boiled up with fresh lye, and, if necessary, some more fat, taking care this time to have an excess of alkali in the solution. Salt is then again added to separate the soap from the liquid, after which the boiling is continued for some hours, in order to perfect the union of the soda with the fat. The lye drains out, and the soap is then ready to be skimmed off, and transferred to the frames in which it solidifies on cooling. It is then cut into bars and dried, and is ready for sale.

The frames are made with movable sides and a porous bottom, so that any lye which may be mixed with the curds shall drain away, and when the soap has solidified the frames are removed, and the block is cut by wires, first horizontally into slabs, and then vertically into bars. In England the frames are all of uniform size, so that a block of soap measures exactly 15 inches wide, by 45 inches long, and 45 inches high.

The above description of the process will serve for a hard curd soap made exclusively from tallow; but for various reasons it is often found desirable to use a mixture of fats or oils, or even of rosin. Castor oil possesses the advantage of readily saponifying, and forming a very hard product, which will take up a large per-centage of water. Cocoa-nut oil has the same characteristic; but it has other specialities, which will be considered presently, when speaking of marine soap. Palm oil is suitable for toilet soaps, an admixture of it communicating a rather agreeable perfume. It may be used to advantage to the extent of 75 per cent. of palm oil to 25 per cent. of tallow.

Rosin will not make a hard soap by itself, as it has too great an affinity for water—so much, indeed, that after having been dried it will become liquid on exposure to the air. It makes, however, a very good compound, either with tallow or palm oil, if limited to about 15 per cent. In no case should it exceed 30 per cent. The rosin should be saponified separately from the fat, and then added to the other after the last boiling described above, continuing the boiling for some time afterwards, until the two preparations have thoroughly combined. Rosin being cheaper than the other substances, the yellow soap thus made has an advantage in price, while for ordinary washing purposes the slight smell peculiar to rosin is not an objection. It, moreover, makes an excellent lather, and is a strong, useful soap.

Oleic acid is very readily saponified, and requires much less boiling than the other substances already mentioned. It may be used either alone, or with tallow or rosin. It makes a good soap, firm, and not affected by the weather.

Olive oil is largely used in the south of Europe instead of tallow, the shores of the Mediterranean being the native soil of the olive. In this country, however, it cannot compete in price with the other articles above named.

Considerable stress is often laid upon having mottled or marbled soaps, and not altogether without reason, because it is not so easy to give them this appearance when containing a large proportion of water. Twenty per cent. may be taken as about an ordinary per-centage in the mottled descriptions. The salts of iron or copper (especially the former) are most generally adopted to produce this effect, which is due to their natural tendency to separate more or less from the mass of soap with which they are mixed, as it cools. If the cooling proceeds rapidly, sufficient time is not allowed for the interchange of the particles, and the soap will present a uniform hue of the colour characteristic of the metallic salt employed. If it is cooled gradually, veins and patches, of a bluish colour in the case of iron, will afterwards be found to extend throughout the mass, which will turn to a reddish colour by the oxidation of the iron on subsequent exposure to the air. It is the conversion of the sulphate into the oxide which furnishes the red mottling of the Castile soap on the exterior surface, while it is of a bluish-black within. If the soap were too watery, the colouring substances would, by their superior weight, find their way to the bottom of the boiling-pan, and the effect desired would be entirely lost.

Fancy soaps, which are made in great variety for the toilet, are usually scented with some aromatic oils. For this branch of the trade the ordinary commercial soaps are used, after undergoing a process of refinement, or a soap is specially made for the purpose from almond oil, or the like. Much taste is shown by the best London makers in the selection and combination of the perfumes, which, along with the colouring matters, such as vermilion, yellow ochre, aniline, etc., are usually boiled up with the soap. To facilitate this operation, as a well-dried soap does not readily melt, it is usually cut up into fine shavings, and after boiling is well worked under rollers until it presents a uniform appearance. If the soap is intended to be highly scented, or very expensive perfumes are to be employed, the cold process is adopted, as much of the strength of the scent is lost by boiling. In this case the soap is shredded as before, and the perfume and colouring matters well amalgamated with it by being worked in a mortar with a pestle. It is then divided into lumps, and roughly moulded with the hand into something of the shape it is finally to assume. After being left on a rack to dry for about a week, it is pressed into a mould, which imparts to the cake the form and device which may be required, and when taken out the edges are trimmed and the surface polished with the hand.

Transparent soaps are prepared by taking an ordinary hard soap and dissolving it in hot alcohol, after having stored it for the purpose of driving off all the water. Soap being completely soluble in this medium, any extraneous matters which it may contain can be readily separated by filtration, care being taken to keep the solution hot during the process. The alcohol is then evaporated out of the filtrate, and on cooling it hardens into a transparent soap. These soaps are coloured, according to fancy, with vegetable colours dissolved in alcohol. This branch of the trade is little practised in England, in consequence of the heavy duty on spirits, which prevents the home manufacturer from competing with those on the Continent.

Soft soaps are made in this country with either potash or soda and the drying oils, the most familiar of which are those extracted from hempseed, rape, and linseed. These oils are deficient in stearine, and on that account are not available for hard soaps. On the Continent potash is much more frequently employed as the alkali instead of soda, potash being comparatively cheap in those countries where wood abounds; but it has such an affinity for water that even when combined with tallow or the non-drying oils, it will not make a firm soap such as will retain its character in a moist atmosphere.

In this manufacture the non-drying oils, or sometimes the fish oils or tallow, are boiled up with a solution of potash, not too strong, until they form a thick sticky fluid, when a stronger lye is added and the boiling continued until it becomes quite clear and slimy. The compound has now to be tested carefully, to see whether there is a proper proportion between the fatty acid and the alkali; because an excess of either the one or the other will become evident on cooling. Having adjusted this properly, the heating is continued, in order to drive off the superfluous water, and the process is accelerated by keeping it constantly stirred. As the evaporation of the water progresses, the substance in the pan becomes thicker, and the froth on the surface diminishes, until the soap settles down in a thick mass at the bottom. The heat is then withdrawn, and when the

contents of the pan have cooled down they are scooped out and put into casks.

Soft soaps, according to quality, contain from 40 to 50 per cent. of water. Sometimes they present the appearance of a clear yellowish jelly interspersed with small grains, which is produced by the addition of a little tallow, the less soluble constituents of which collect in small granules. At other times they present a uniform green colour, which is a natural result if the soap has been made from hempseed oil, but which is often produced artificially by the admixture of indigo in a yellow soap. Both the colour and the granulation are mere fancies in the trade, and have no other necessary connection with the manufacture.

With the drying oils, soft soaps may be made with soda; other fats and oils besides those already named may be used with a mixture of soda and potash, in which the latter predominates.

The hard soaps should be as nearly as possible neutral; but the soft soaps are not separated from the lye by the addition of salt, as in the former, so that they always retain an excess of alkali. They are principally used for scouring manufactured goods in the bleaching and dyeing works, and will be found mentioned in Lessons I. to IV. of this series, which treat of such operations.

Marine soap is made of cocoa-nut oil. Whilst a very small quantity of salt will separate the curds produced by the saponification of any other oil, it has no effect upon this. A very strong brine is necessary for the purpose; but that is found to be unsuitable in practice, as the brine takes up the water at the same time, and leaves so hard a curd as to be unmanageable. It has such a tendency to harden under any circumstances that the oil is boiled with the very strongest caustic soda lye, care being taken that the alkali be not in excess, in which case the use of salt can be altogether dispensed with. The operation is facilitated by the replacement of some of the soda by potash. A cocoa-nut soap made with soda will hold upwards of 70 per cent. of water, and still be so firm as to deceive the uninitiated; however, it is, of course, proportionately weak in its cleansing properties. Its resistance to the effect of a weak solution of salt indicates its value on shipboard, other soaps being absolutely useless for washing in sea-water.

Incredible as it may appear, flints, sand, or pipe-clay may enter pretty largely into the composition of soaps, both hard and soft, and that without injury to their useful properties. The silica contained in them is reduced to a soluble state by being melted in a reverberatory furnace with caustic soda or potash, then ground fine, and lastly boiled in an aqueous solution of the alkali, the result of which is that the silica forms a transparent gelatinous mass, sometimes known by the name of soluble glass. When the soap has been thoroughly boiled, the silicate of soda is mixed with it in the pan, and the compound is then transferred to the frames to cool and harden. As in the other processes, potash is only used when a soft soap is intended to be made. These soaps are cheaper than those made exclusively from oils and fats, while at the same time they fulfil their purpose very satisfactorily.

TECHNICAL DRAWING.—XXIII.

THE TEETH OF WHEELS.

Fig. 229.—*To trace a cycloid* by mechanical means.*

Fasten a rail of wood, or any straight edge, to a board.

Take a circular piece of wood, cut a small notch at any point in the edge (as at A), and fix a small knob or button in the centre (B).

The point of a pencil held in the notch, whilst rolling the disc along the straight edge by means of the knob, will describe a cycloid.

In order to prevent the disc slipping as it rolls along, it is advisable to glue a narrow strip of sand-paper round the edge of both disc and rail.

If, instead of a straight piece of wood, a circle or arc be employed, the curve traced by the pencil will be an epicycloid; if the inner side of a hoop be used, the curve will be the hypocycloid.

Now if the same generating circle be made to roll on the outside of a circle, and again on the inside, both curves starting from the same point, the portion inside the circle (the hypocycloid) will give the curve for the flank of the tooth, and the cycloid on the outside will give the face or point of the tooth.

This will be clearly understood when put into practice, and for this purpose the attention of the student is directed to Fig. 230.

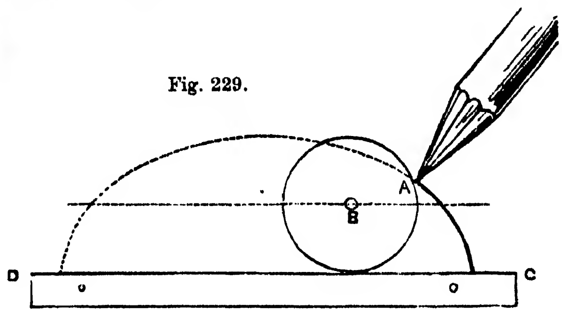
In this figure A and B are the centres from which the pitch-circles A′ A″ and B′ B″ are struck. These circles touch each other at C.

Now if the epicycloid C D be drawn from C, then a portion of it, C F, will be the face or point of the tooth; and, again, if by means of the same generating circle a hypocycloid, E C, be traced from the same point, the portion C G will be the flank of the tooth. Of course, if similar curves are drawn from H, in the reverse direction, the opposite side of the tooth will be described.

The length comprised by a tooth and a space is called a *pitch*. This is, of course, equal to the distance from the centre line of one tooth to that of the next one.

The following data are those generally adopted by millwrights and engineers:—

Fig. 229.



Supposing the "pitch" to be divided into 15 equal parts; that is to say—

Height of tooth outside the pitch-circle	5½	parts.
Depth of tooth within the pitch-circle	6½	,,
Thus the total height of the tooth is	12	,,
Width of tooth	7	,,
Width of space between the teeth	8	,,

Some engineers, however, adopt the following proportions, and they are, therefore, used occasionally in the examples:—

The pitch divided into	11	parts.
Width of space	$\frac{6}{11}$	,,
Width of tooth	$\frac{5}{11}$	,,
Depth of flank	$\frac{4}{8}$	,,
Height of face	$\frac{3}{8}$	,,

Although teeth are designed and the patterns for them are made on the scientific principles shown, it is usual in most drawings to consider the curves as portions of circles, which may be drawn with such approximate correctness as to be sufficiently accurate for general purposes of drawings—the length of a pitch being, as a rule, taken as the radius. The face of the tooth, A E (Fig. 231), is struck with this radius (the pitch), and the flank, A D, is struck from C, the centres being in the pitch-line B.

Now it will be noticed that the flank of the tooth under consideration bends inward about the middle, between A and D. This may be avoided by employing a circle of centres—that is, a circle a little outside the pitch-circle—and although using the pitch as the radius, fixing the centres on this additional circle. Thus, place the steel point of the bow compass at F on the additional circle, but strike the flank from G.

It will be seen that by these means the evil alluded to is avoided: the tooth thus becomes broader at the base, and consequently stronger.

It will be found that when the diameter of the generating circle is equal to the radius of the circle in which it rolls, the hypocycloid is converted into a straight line; therefore, when

* The cycloid was invented by Galileo, an eminent mathematician and natural philosopher. He was born in Pisa in 1564, and died in 1642.

the one wheel is of half the diameter of the other with which it is geared, the flanks of the teeth, instead of being curves, are straight lines tending towards the centre, and they are hence called *radial* teeth. Two such are shown in Fig. 232.

As teeth so formed are, however, necessarily narrower at the bottom than on the pitch-circle, they would be weaker at that part, the radial flanks are not drawn quite down to the root, but are turned off by small quadrants, by which means they are materially strengthened: this is shown at A in Fig. 232, and will be further illustrated in future examples. In order to strengthen the teeth, flanges are sometimes cast on one or both sides.

Fig. 233.—*To draw radial teeth to gear with each other.*

Draw the pitch-circles, touching each other in T.

From T set off a pitch on each of the pitch-circles—viz., T A and T B.

Join A and B. Bisect A B by the line C, and produce it.

From A draw the radius A D.

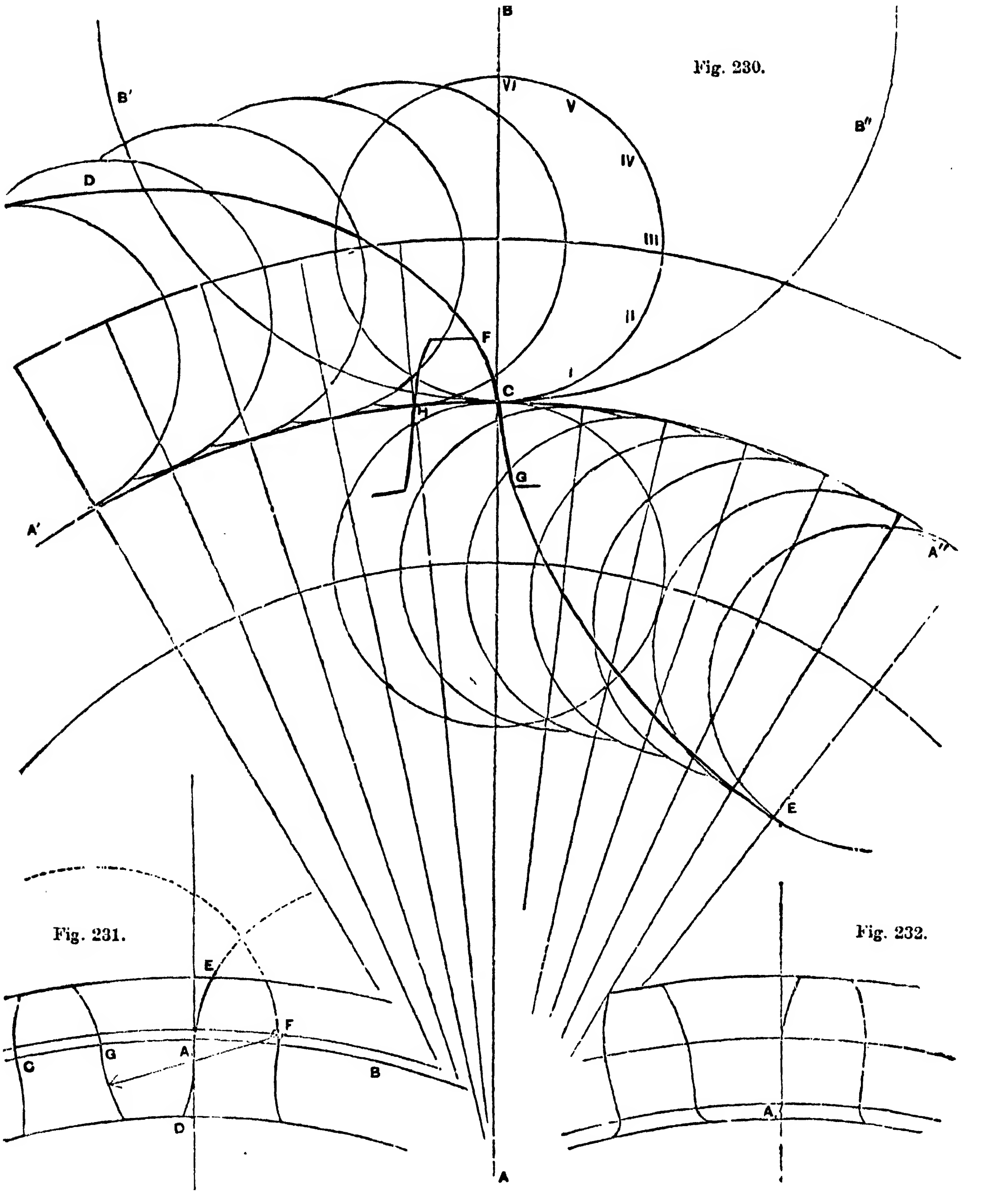


Fig. 230.

Fig. 231.

Fig. 232.

From B draw the radius B E.

At A draw a line at right angles to A D, cutting the bisecting line C in F.

At B draw a line at right angles to B E, cutting the bisecting line C in G.

From the centres of the circles to which these tangents are drawn, draw circles through F and G, and these will be the circles of centres for the faces of the teeth.

Now set off the pitches around the pitch-circles, and divide them into teeth and spaces. In the present example the tooth is taken at $\frac{5}{11}$ and the space at $\frac{6}{11}$ of the pitch, the height outside the pitch-circle being $\frac{3}{8}$ and within the pitch-circle $\frac{4}{8}$ of the pitch.

The radial flanks are now to be drawn, and turned towards the bottom by means of arcs, as directed in Fig. 232.

Fig. 234 is inserted to remind the student of one of the methods of dividing a line proportionately to another.

In this figure let A B represent the length of the pitch, which it is desired to divide in the proportion of five-elevenths and six-elevenths.

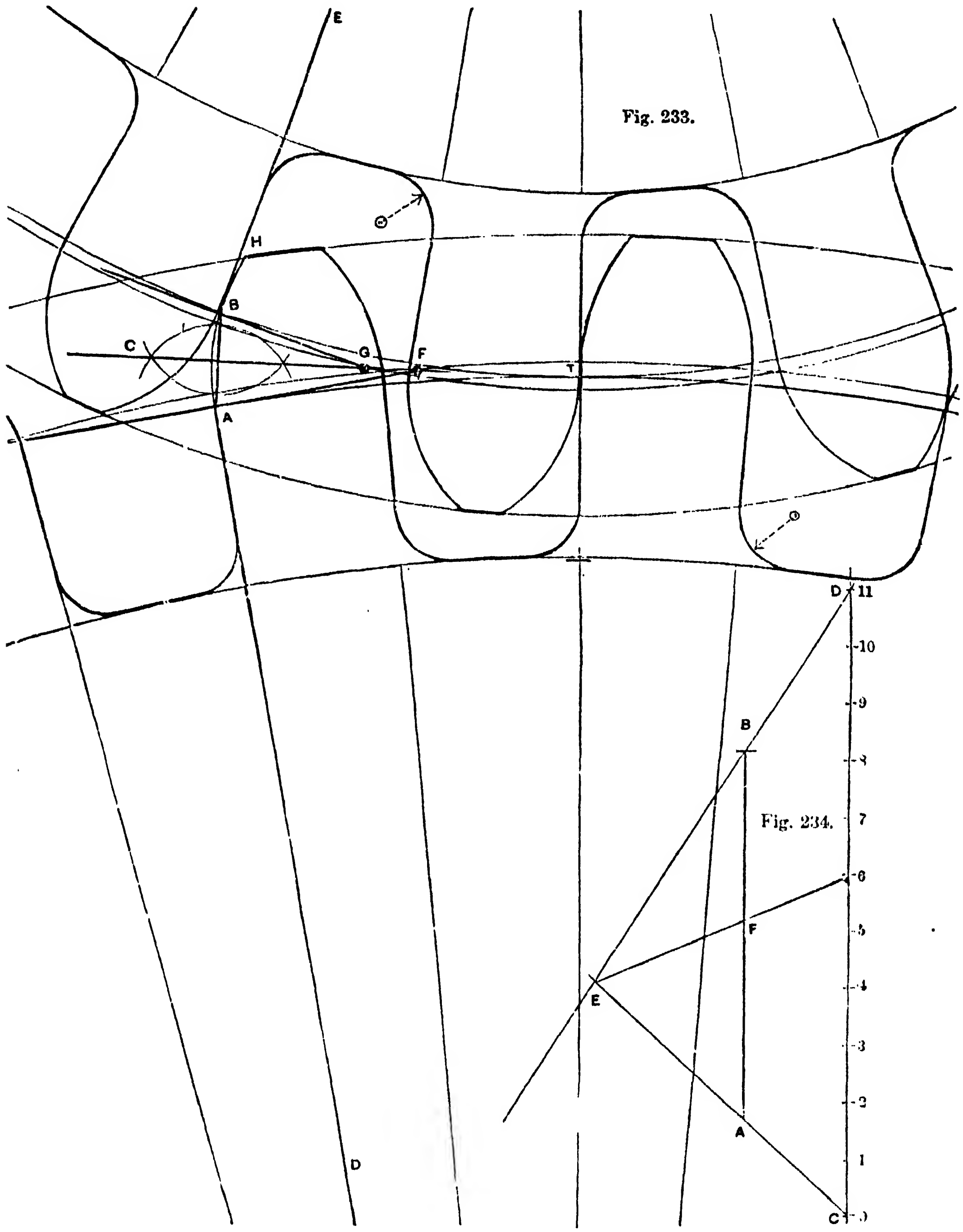


Fig. 233.

Fig. 234.

Draw the circles in the way which has frequently been shown for the root and points of the teeth.

From F, with radius F A, describe the arc A H, which will be the face of the tooth; and with this radius, and from the same circle of centres, the faces of all the rest of the teeth of the large wheel are to be struck.

The faces of the teeth of the smaller wheel are to be struck with the radius G B.

Draw any line, C D, parallel to A B, and set off upon it eleven spaces. These may be any length.

Draw lines, D B and C A, uniting the ends of the two lines, and meeting in E.

From the point marked 6 draw a line to E, which will divide A B in F in the desired proportion.

EDUCATION AT HOME AND ABROAD.

X.—CIRCULATION OF WORKS OF ART (*continued*)—EVENING TECHNICAL INSTRUCTION.

BY SIR PHILIP MAGNUS.

IN connection with the South Kensington Museum, there exists an art library having a collection of nearly 60,000 volumes, upwards of 24,000 drawings, and 59,000 photographs.

Whilst the loan of objects of art from the central museum to local schools of art or to local museums is of great value as aid to the teaching of art, and as a means of elevating and improving the taste of artisans and of the public generally, it might with advantage be supplemented by the gift to provincial museums of reproductions of artistic works, or of duplicates of such works, when they exist. The Commissioners on technical instruction were particularly struck with the excellence of the museums attached to schools of art in the more important manufacturing centres of the Continent. Many of these museums contained valuable historical collections of works, illustrating the staple industries of the district, and from all we were able to learn they were much frequented by artisans. The museums at Mulhouse and at Crefeld, the centres of the cotton-printing and silk industry of Germany, contain typical collections of examples connected with the manufactures of these towns. In the conclusion of their report on technical instruction, the Commissioners remark: "Whilst we fully admit the force of the contention that the contributions of the State to the foundation and maintenance of museums will be of the greatest service to the country at large, if applied mainly to central institutions, like those of the metropolis, of Edinburgh, and of Dublin, we highly approve of the grants to provincial museums of reproductions either gratuitously or at a very low rate. These grants may, even in the case of typical museums situated in some of the chief industrial centres, be extended with advantage to original examples of art, and of manufactures calculated to increase the knowledge and improve the taste of those (more especially of the artisans) engaged therein."

The influence of industrial museums in technical instruction is gradually being more appreciated in this country, mainly through the action of the Science and Art Department. Manufacturers, however, do not yet seem to fully recognise the real value of such collections. They show very little interest in the development of these museums, and shrink from co-operating in improving and adding to the collections to the same extent as is done by Continental manufacturers. The heads of firms in this country have a greater distrust of one another than is the case abroad. In many foreign museums are found collections of all the newest patterns contributed by those engaged in the same trade, and these collections are open to the inspection of the general public. In this way, each manufacturer benefits by the work of others, and the general industry of the town is improved by the opportunities thus afforded for the better education of the workmen, the managers, and the masters. The study of new designs exhibited in a museum of this kind helps to form the taste and to improve the designing power of all who are engaged in the industry. Of those who visit such a museum, some, owing to natural aptitude or to superior education, will make better use of their opportunities than others; and in this respect such museums are very similar to schools the pupils of which benefit in very different degrees from the education they therein receive. This co-operation of manufacturers to benefit the trade in which they are engaged, which is particularly exemplified in the educational agencies of Mulhouse, and is in striking contrast to the "trade secret" theory of the majority of English manufacturers, is founded on the belief, entertained very generally on the Continent, that it is more advantageous to manufacturers to compete with foreigners than among themselves, and that everything that tends to increase the technical knowledge and artistic skill of those working at their own trade helps them to produce superior goods, and so to successfully compete with manufacturers abroad.

Later on, further particulars will be given with respect to some of these foreign trade museums and to their industrial influence. I have been induced to refer to the subject here on account of its connection with the circulation of works of art as organised by the Science and Art Department, and with the encouragement afforded by the Department to the establishment of local museums in the great centres of trade. The subject of museums is only incidentally associated with that of the evening instruction of artisans which we have been considering; but it seemed appropriate to consider it, whilst reviewing the several different ways in which the Science and Art Department is directly and indirectly assisting in educating the industrial classes of this country.

EVENING CLASSES IN TECHNOLOGY.

Whilst mathematics, drawing, and the elements of science constitute the basis of all technical instruction, persons engaged in various industries require to have explained to them the application of these subjects to their special trades, and the *rationale* of the different processes and operations that are carried on in their several workshops. Instruction of this kind includes what is generally understood by Technology. A knowledge of the technology of a trade constitutes an important part, but not the whole, of an artisan's education. One may teach back from the technology of a trade to the principles of science therein involved; or, commencing with scientific principles, one may lead up to the application of those principles to special manufacturing processes or trade operations. The former method is better adapted to the education of adults or persons already familiar with workshop practice; the latter is the more scholastic, and is generally adopted with younger students and with those who have more time at their disposal for study. In either case the principles of science must be known; and hence the system of evening instruction so extensively encouraged by the Science and Art Department, to which reference has been made in the preceding articles, is an essential part of our present system of technical education. But it was long ago felt that the teaching of the elements of science and of drawing, without any reference to the particular trades in which the artisans receiving such instruction are engaged, does not afford as complete an education to our working classes as they require; and accordingly the Society of Arts—to which body so many movements for the improvement of arts and manufactures in this country are due—mainly at the suggestion of Colonel Donnelly, arranged examinations in the technology of a few important trades, and offered prizes to encourage candidates to present themselves for these examinations. Owing greatly to the difficulty of finding teachers, and to the fact that the Society of Arts was unable to offer any remuneration to teachers in the nature of payment on results, these examinations exerted no appreciable influence on the progress of technical education. In the year 1873, when the first examination was held, the number of candidates was only 6, the subjects chosen being alkali manufacture, steel manufacture, and carriage-building; in 1874, there were 36 candidates; in 1875, 46 candidates in 8 subjects; in 1876, 62 candidates in 7 subjects; and in 1877, 68 candidates in 8 subjects. In this year the Clothworkers' Company, always to the front in the promotion of technical education, placed a sum of money at the disposal of the Society of Arts for the payment of teachers of technology on the same principles as the teachers of science are paid by the Department; and to this action of the Clothworkers' Company was due the impulse that was given to the establishment of technical classes in all the principal centres of trade in this country. In 1878 the number of candidates increased from 68 to 184; and in 1879, when the examinations were conducted under the direction of the Committee of Guilds associated for the promotion of technical education, incorporated the following year as the City and Guilds of London Institute for the Advancement of Technical Education, the number of candidates was 202. Between the years 1873 and 1879 the number of candidates had increased from 6 to 202, and examinations were held in the following subjects: the manufacture of cotton, paper, silk, steel, pottery and porcelain, gas, glass, cloth, alkali, carriage-building, agriculture, silk-dyeing, wool-dyeing, calico-bleaching, telegraphy, and blowpipe analysis.

In 1880 the City and Guilds of London Institute arranged for the payment of teachers of technical classes under conditions similar in many respects to those under which the teachers of science classes were paid by the Department. Fresh subjects were added to the examination, and the strin-

gency of the regulations under which the examinations had previously been conducted by the Society of Arts was relaxed. The result of these changes was a considerable increase in the number of candidates. In 1882 further changes were introduced. The intermediate or advanced stage of the examination was abolished, and candidates were required to choose between the "ordinary" and the "honours" grade. It was felt that the study of technology must necessarily be preceded by the study of the elements of some branch of science, and that a two years' course of instruction in technology was sufficient, in addition to the preliminary lessons in pure science. Of the two grades of the examination, the "ordinary" was intended for apprentices and workmen, and the "honours" for foremen and managers. The subjects were re-arranged and classified, and new subjects were again added to the programme, the chief of which were weaving and pattern designing and electrical engineering.

The Institute, in its early days, experienced great difficulty in obtaining competent teachers. The choice lay between the ordinary science teacher, who had acquired a superficial knowledge of some branch or branches of elementary science, but who knew very little of the technical details of any one trade, and the foreman of works, who was quite familiar with the processes he daily saw in operation, but who was unable to give the reason of those processes or to connect them by any causal links with the principles of science. During the first year or two of the Institute's existence, the science teacher was accepted as the preferable of these two classes of instructors; but, subsequently, efforts were made to combine the two, and those teachers only were registered who were qualified to teach science classes under the Department and who could give evidence of having acquired in the factory or workshop a practical knowledge of a certain industry. Much has been said and written about the advantages of workmen-teachers for technical classes. Of the importance of having teachers conversant with the details of the trade they profess to teach there can be no doubt; but it must be remembered that a technical teacher should be able to do something more than give instruction in the operations of a trade as practised at the time: he should be able to suggest directions in which improvements may be effected, and so try to train up a body of workmen who will be not only equal, but superior, to those who have preceded them. Teachers who are to do this must be men of scientific attainments. That they should be practically acquainted with the processes of the trade they are to teach is equally essential. "The teacher who is to inspire confidence in his artisan students must address them in the language they understand, and must show that he is not beyond appreciating practical difficulties which occur to them in their daily work." "Indeed, the technical teacher ought to be so constituted as to be able to keep one eye on the general principles of science and the other on the industry which his pupil intends to follow." Teachers of this kind are not easily found; and yet the progress of technical education in this country depends greatly upon the supply. Referring to the deputations of working-men who expressed their views on this subject to the members of the Commission on Technical Instruction, the Commissioners say: "We believe that many workmen are disposed to attach too little value to the importance of acquiring a knowledge of the principles of science because they do not see their application. We are of opinion that, whenever it is possible, persons engaged in the trade taught, and having scientific knowledge, should give instruction to workmen; and we have ascertained that a large number of such teachers are registered under the examination scheme of the City and Guilds of London Institute."

As we have already pointed out, it might be better in all technical classes to teach the principles of science through their applications, and so to lead the student generally to inquire into causes through the desire to understand the machinery and processes with which he is familiar in his daily work. But such a method of instruction could be carried out by those teachers only who are at once practically acquainted with the technical details of a manufacture or trade, and also with the general principles of science. Practice and principle might thus be taught together, the one assisting the other. When the Technical Institute, however, came into existence, it found a centralised system of science-teaching, with ramifications in all parts of the kingdom; and as the classes so formed were State-aided and assisted by a considerable grant, the Institute, in order not to duplicate, at a cost it could not afford, the machinery of the Department, limited its operations to the supplementing of teaching in science by instruction in technology. As already stated, this system, in which the science is taught separately from its applications, and without any reference thereto, is perhaps not the best possible for the majority of artisans; and that it is not the most acceptable method of instruction to those engaged in industrial pursuits is shown by the fact that, of the students who eagerly avail themselves of the Institute's classes in technology, only a small proportion have previously attended the Department's classes in science. This proportion, however, is likely to become greater as the rudiments of science are more generally taught in elementary schools; and seeing the importance of a knowledge of the principles of science for the proper comprehension of the theory of every trade into which machinery enters, this division of technical instruction was inevitable.

PRACTICAL PERSPECTIVE.—III.

FIG. 14 is a representation of the interior of a hall, having a floor covered with square slabs of alternate white and black.

This view is not drawn to any particular scale. Having drawn the general outline or rectangle, fixed the centre of the picture, and drawn the horizontal line, the points of distance must next be marked. These (as in the present illustration) need not be on the paper, but may be on the board or table on which you are drawing.

From the four angles of the figure draw lines to the centre of vision, which will give the lines of junction between the floor and ceiling and the walls.

Now this hall is supposed to be twice as long as it is wide. The floor thus consists of *two* squares.

Therefore, from A and B draw lines to the points of distance. These will give the points C and D. Join C and D, and this will complete *one* square of the floor.

Again, from C and D draw lines to the points of distance, and these will give the points E and F.

Draw E F, then A E F B will be the perspective representation of the floor.

From E and F draw perpendiculars, cutting the upper edges of the wall in G and H.

Draw the line G H, which will complete the view of the interior. The windows and doors are necessarily omitted in this study.

Now divide the line A B into the number of parts corresponding with the number of slabs to be placed on the floor, and from these points draw lines to the centre of vision.

It will be seen that these lines, 1, 2, 3, 4, 5, 6, will pass through the diagonals A D and B C, and also through C F and D E.

Thus lines 1 and 6 will cut the diagonals in *a* and *b*. Through these points draw a horizontal line, which will give the front row of squares. Lines 2 and 5 will cut the diagonals in *c d*. Through these points draw another horizontal line, which will give the second row of squares.

Lines 3 and 4 will cut the diagonals in *e* and *f*. Through *e* and *f*, therefore, draw a horizontal line, which will give the third row of squares.

By continuing this method, the entire surface of the floor will be covered with squares, each diminished in size or altered in form according to its position.

The system of working by scale having been shown in several of the earlier studies, it will not be necessary to our purpose to give the measurements in every case; but it will be evident that all the principles of perspective here laid down can be equally well applied, whatever may be the relative size of the objects or the height of the spectator. All measurements in the future figures are therefore assumed, leaving it to the student to work them to any scale he may think proper.

Fig. 15.—In this study it is required to put into perspective a square, the surface of which is at right angles to the plane of the picture, and which is divided into nine equal squares.

Having drawn the picture-line and horizontal line, and having

fixed the centre of the picture and the points of distance, set off from A the length A A', representing the distance of the front edge of the square on the left of the spectator. Make A' B equal to the height of the required square, and from A' and B draw lines to the centre of the picture. From A' set off on the picture-line A' D equal to A B. From D draw a line to the point of distance, cutting A C in D'.

At D' erect a perpendicular, cutting B C in C'. Then A' B C' D' is the perspective representation of the square placed at A', at right angles to the picture-plane. Divide A' B into three equal parts by the points E, F. From E and F draw lines to the centre of the picture, cutting C' D' in G and H.

These lines will divide the squares horizontally into three equal strips.

Divide the length A' D into three equal parts by the points I, J.

From I and J draw lines to the point of distance, cutting A' D' in I', J'.

At I' and J' erect perpendiculars, cutting B C' in K and L. These will divide the perspective view of the square vertically into three strips, and these will become gradually narrower as they recede, although representing spaces of equal width.

Another method of dividing the square would be to draw diagonals. Then the lines E and F, cutting these, would give the points through which the lines I', J' should pass. This method is only of use, however, where the figure to be divided is a *square*, whilst the method shown is equally applicable to any parallelogram.

Fig. 16.—This is an application of the foregoing figure, and represents a wooden case divided into compartments. Having marked the point M, representing the distance of the front of the object from A, draw the parallelogram M N O P, which shows the depth of the side of the case.

Draw the perspective view of the front of the case as in the last lesson; then, instead of dividing it into three equal parts, as in the line A' B in the previous figure, set off upon the line corresponding with A' B the spaces representing the thickness of the wood of which the carcase of the case and the shelves are made, and draw lines from these points to the centre of the picture.

Next set off within the space on the picture-line which represents the real width of the lower edge of the case the thickness of the sides of carcase, the upright partitions, and the distances between them. From these points draw lines to the point of distance, which, cutting M C, will give the points at which vertical lines are to be drawn.

In this study the case is represented as square; but the method of working would be the same, whatever might be the proportion of the breadth to the height.

The horizontal lines showing the junction of the sides of the compartments will complete the object.

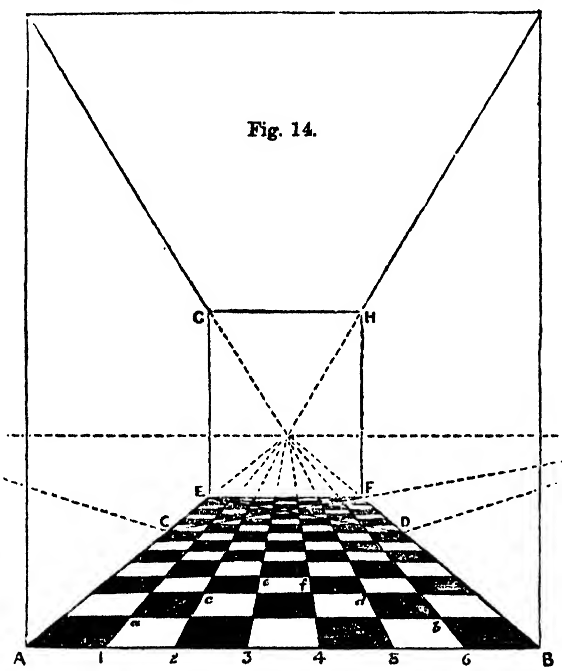


Fig. 14.

EXERCISE 8.

There is a case of shelves against a wall: the case is 8 feet high and 4 feet wide; it has three shelves placed so as to divide the case into four equal spaces. The wood of which the case and shelves are made is 1 inch thick; scale, 1 inch to the foot. The height of the spectator is 5 feet 6 inches, and his distance 15 feet. The front of the object is to be parallel to the picture-plane, at 6 feet on the left of the spectator.

EXERCISE 9.

Give a perspective view of the same object when at 10 feet on the right of the spectator, and 8 feet within the picture, when its front is at right angles to the picture-plane. Height of spectator, distance, etc., the same as in the last exercise.

Fig. 17.—In this study only a portion of the picture-plane is used; the centre of the picture being placed at one side, and the point of distance at the other.

The subject of the study is a cube, placed first in the foreground, and then at different distances within the picture.

The length from A to B represents the distance of the cube to the left of the spectator, and B C' is the length of its edge.

From C' and B draw lines to the centre of the picture; and, as shown in Fig. 13 (1), the cube, as it moves backwards at right angles to the picture-plane, will travel in this track.

From B set off D, equal to the side of the cube, and draw a line to the point of distance. This line drawn from D will cut B C in D'; and a horizontal line from D' to cut C C' in C'' will give the distant edge of the ground-plan of the cube.

It will next be advisable to draw the perspective views of the ground-plans of the two other views of the cube.

From D set off D E, equal to the distance between the back of the first cube and the front of the second. Draw a line from E to the point of distance, which, cutting B C in E', will give the position of the second cube; and a horizontal line drawn from E', cutting C' C in E'', will be the front edge of the plan.

It will thus be seen that E' E'' represents C' B when it has receded to the given distance.

Now a line drawn from E to the point of distance, cutting C' C in F, would be a diagonal of the square base of the cube. Therefore a horizontal line drawn from it would give F F', and complete the plan. But, as already remarked in the former figure, this method would apply to the square only; and therefore another method is shown—viz., set off on the picture-line from E the *real* length of the distant side, whatever that may be. The point F is outside the present figure; but the line drawn from it to the point of distance will be seen to cut B C in F', which gives the position of the back line of the plan. The third plan is to be drawn in a similar manner—viz., by setting off from the last point on the picture-line the distance of the next cube and the width of its side, and drawing lines to the point of distance, cutting B C in G' and H. Then, as in the previous case, horizontal lines will give the front and back edges of the plan required.

Now on C' B construct a square, representing the front of the first cube; and from the two upper angles, I and J, draw lines to the centre of the picture.

On E' E'' and G G' erect perpendiculars, and these will be cut by I C and J C at the required height. Horizontals being then drawn at the points where the perpendiculars are cut off, will complete the fronts of the two distant cubes.

The perpendiculars D', F', and H will give the distant edge of the side of each cube, and the position of the rest of the lines to complete the transparent appearance of the objects will be readily understood from the diagram.

EXERCISE 10.

Scale, ½ inch to the foot. Height of spectator, 6 feet; distance, 15 feet.

(1.) Put into perspective a cube of 4 feet edge, when its front is parallel to the picture-plane, at 6 feet on the left of the spectator, and 5 feet within the picture.

(2.) Put into perspective a cubical figure 2 feet square at base, and 9 feet high, when at 8 feet on the right of the spectator, and 10 feet within the picture.

Fig. 18 is a cubical figure, or block of stone, which is much higher than the eye of the spectator; and for this reason the top, of course, cannot be seen. In order, however, to account

for this appearance, the object is drawn as if transparent, and thus the upper surface of the bottom and the under surface of the top become visible. The student is recommended to work all his figures in this way, as the interior lines act as a check on the exterior ones, and many inaccuracies are often thus discovered.

In order that the student may test his present knowledge of the method of working pursued, these figures are not lettered; but all the working lines are clearly shown, and the construction will now be described.

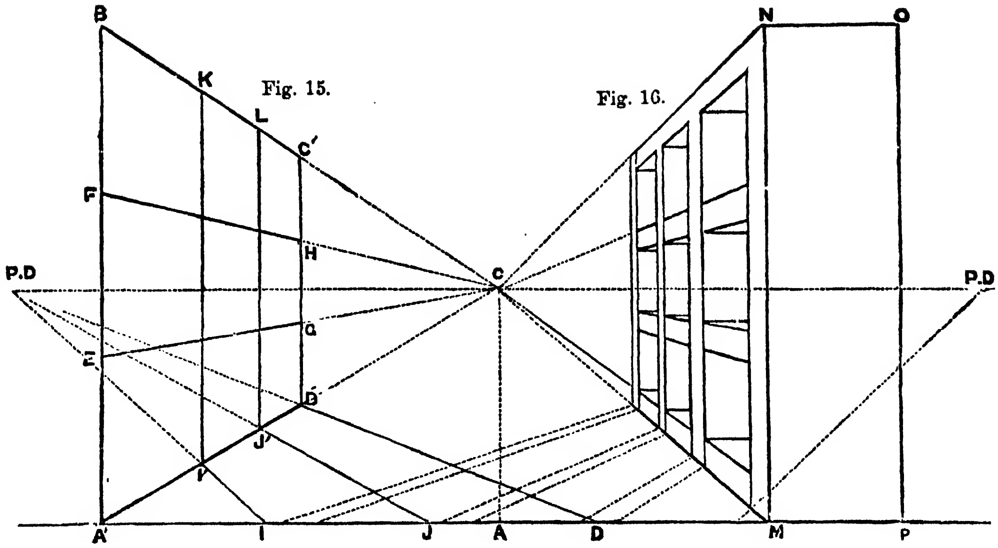


Fig. 15.

Fig. 16.

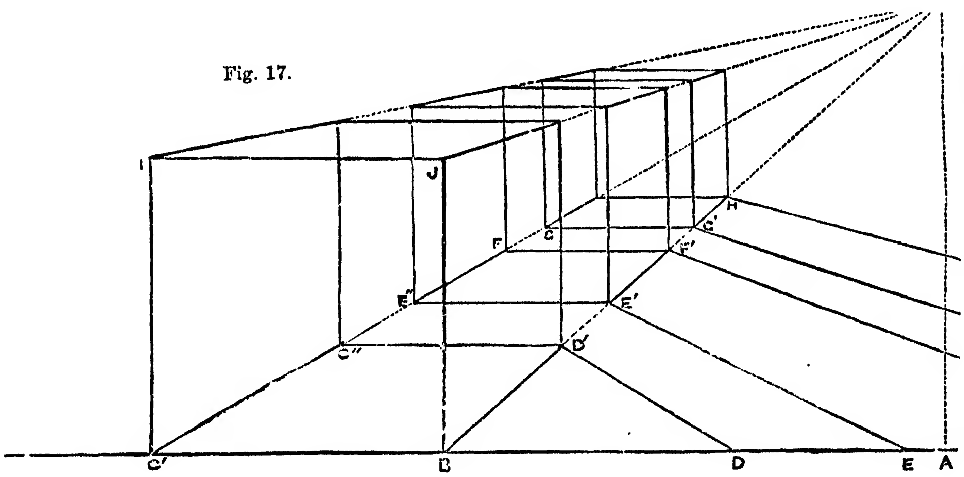


Fig. 17.

The base of the block is a square, and it is placed on the left side of the spectator, at a distance which may be assumed, or which would be named in the question to be worked.

Whatever this distance may be, set it off on the picture-line from the point immediately under the centre of the picture; and from this point again set off the width of the square base.

From both the last-mentioned points draw lines to the centre of the picture; then from the first one set off the real length of the distant side of the base, and draw a line to the point of distance; this will cut the line drawn from the end of the front of the base to the centre of the picture, and will give the point at which the horizontal line forming the back edge of the plan is to be drawn.

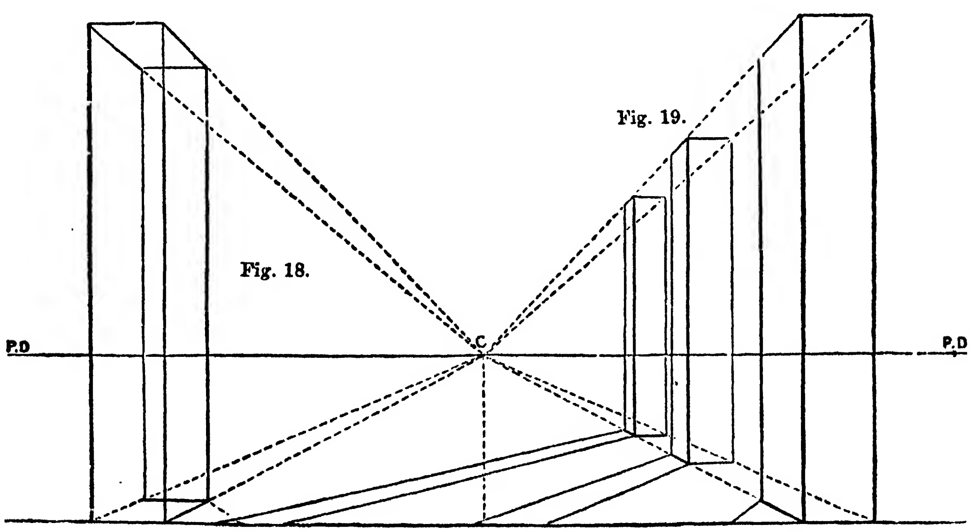


Fig. 18.

Fig. 19.

Now draw the front elevation of the block of such height as may be required, and from both the upper angles draw lines to the centre of the picture. The distant perpendicular is then to be drawn from the back angle of the base, and the interior lines will then follow in their places.

Fig. 19.—This figure will afford further practice in placing objects in the distance, and the principle having already been fully explained in relation to the figures, it will merely be necessary to pass rapidly through the directions for working this study.

Having drawn the plan as in Fig. 18, mark off on the picture-line the distance between the columns; draw lines from these points to the point of distance, and these, cutting the line drawn from the end of the front edge of the base, will give the positions for the bases of the distant columns.

From these plans erect perpendiculars, which will be terminated by the lines drawn from the upper angles of the object in the foreground to the centre of the picture, and these being connected by horizontal lines will complete the view.

NOTABLE INVENTIONS AND INVENTORS.

VIII.—POTTERY AND PORCELAIN.

The essential ingredients of pottery and porcelain are silica and alumina. Pottery is opaque, while porcelain is translucent. Wares of either kind are *soft* and *hard*, distinctions which relate as well to the composition of the ware as to the temperature at which it is made solid. Common bricks and earthenware vessels, pipkins, pans, and similar articles, are soft; while fire-bricks and crockery are hard. Soft pottery consists of silica, alumina, and lime, and admits of being scratched with a knife or file. Stoneware is composed of silica, alumina, and baryta, and may be regarded as a coarse kind of porcelain. Hard porcelain contains more of alumina and less of silica than the soft; it is baked at a stronger heat, and is more dense. Soft porcelain contains more silica than the hard, and is also combined with alkaline fluxes, so that it may easily be scratched, and it is less able to resist a strong heat.

Clay is so generally diffused, and is of such plastic nature, that articles made of it may be said to belong to every people and to all times. The first drinking-vessels were, doubtless, sun-baked, and consequently very destructible; and it was not until the action of fire was discovered that permanence could be given to these articles. The sun-dried bricks of Egypt, Assyria, and Babylonia have, however, been preserved to the present day, and "not only afford testimony to the truth of Scripture by their composition of straw and clay, but also, by the hieroglyphics impressed upon them, transmit the names of a series of kings, and testify the existence of edifices, all knowledge of which, except for these relics, would have utterly perished. Those of Assyria and Babylon, in addition to the same information, have, by their cuneiform inscriptions, which mention the localities of the edifices for which they were made, afforded the means of tracing the sites of ancient Mesopotamia and Assyria, with an accuracy unattainable by any other means. When the brick was ornamented, as in Assyria, with glazed representations, this apparently insignificant but imperishable object has confirmed the inscriptions of the walls of Babylon, which critical scepticism had denounced as fabulous. The Roman bricks have also borne their testimony to history. A large number of these present a series of the names of consuls of imperial Rome; while others show that the proud nobility of the Eternal City partly derived their revenues from the kilns of their Campanian and Sabine farms" (Birch's "Ancient Pottery"). Among the Assyrians and Babylonians, clay was used as a material for writing on. The traveller Layard discovered in the palace of Sennacherib a whole library of clay books, consisting of histories, deeds, almanacks, spelling-books, vocabularies, inventories, horoscopes, receipts, letters, etc. About 2,000 of these clay books of the Assyrians have been discovered: they are in the form of tablets, cylinders, and hexagonal prisms of terra-cotta.

The potter's wheel, to give symmetry of shape to clay vessels, is represented on the Egyptian sculptures; it is mentioned in Holy Scripture, and was in use at an early period in Assyria. The very oldest wares of Greece bear marks of having been turned upon the wheel. The art of firing the ware is also of the highest antiquity. Remains of baked earthenware are common in Egypt in the tombs of the first dynasties; and the oldest bricks and tablets of Assyria and Babylon, and remains of Hellenic pottery, bear evidence of having passed through the fire. As the clay is by this process rendered porous, and incapable of holding liquids, glaze must have been early employed; and numerous fragments testify to the use of enamels amongst the Egyptians and Assyrians, and glazing among the ancient Greeks and Romans. With respect to form, the Greek vases, by their beauty and simplicity, have become models for various kinds of earthenware; while the application of painting to wares has transmitted to us much information respecting the mythology, manners, customs, and literature of ancient Greece. Even the Roman lamps and red ware illustrate in their ornaments many customs, manners, and historical events. The largest vessels of clay formed by the Greeks were the casks, one of which—and not a *tub*—was used by Diogenes for a residence when he begged Alexander to stand out of the sunshine. These casks were too big to be formed on a wheel, and so required great skill in making.

The ancient pottery has its distinctions of time and place, as between the rude urns of the early Britons and the more carefully finished specimens of their Roman conquerors. The simple, unglazed earthenware of Greece contrasts with the more elaborate Etruscan forms, the finest of which, however, are probably by Greek artists; and the red and black potteries of India contrast with the black and white potteries of North America, the latter being interspersed with bivalve shells. Among the ruins of Central America have been found specimens of pottery considerably in advance of the arts assigned to the ruins, namely, 1000 B.C. These specimens had been formed without the assistance of the potter's wheel; but they are well baked, the ornaments are in different colours, and they are coated with a fine vitreous glaze, such as was unknown in Europe until about the ninth century.

Porcelain is of modern introduction into Europe, but it was known in China more than a century before the Christian era. The Chinese improved their art during four or five centuries, and then, supposing themselves to have attained perfection, they allowed it to remain stationary. So completely was the manufacture identified with that nation, that, on the introduction of porcelain into Europe by the Portuguese in 1518, it received the name of "china," which it still partially retains. The Chinese continued to supply us with porcelain during many years. It was supposed that the fire-clay, or kaoline, used in its production was peculiar to China, and that it was, consequently, hopeless to attempt to manufacture porcelain in Europe.

While the Chinese were improving their manufacture, the art of making decorative pottery became lost in Europe. It was revived by the Mahometan invaders of Spain, whose tiles of enamelled earthenware are to be seen in the Moorish buildings of Seville, Toledo, Granada, and the Alhambra. They are of a pale clay, "the surface of which is coated over with a white opaque enamel, upon which the elaborate designs are executed in colours." The Spaniards acquired from the Moors the art of manufacturing enamelled tiles, and they still continue to be made in Valencia.

The Hispano-Arabic pottery (as it is called from being adorned with Arabic inscriptions) is the prototype of the Italian majolica, the enamelled ware of Italy, dating from the twelfth century. It is related that a pirate king of Majorca, about the year 1115, was besieged in his stronghold by an army from Pisa, and being vanquished, the expedition returned to Italy laden with spoil, among which were a number of plates of Moorish pottery. They were not imitated until the fourteenth century, when specimens of majolica—so called from the island of Majorca—were produced; they resemble the Moorish examples in having arabesque patterns in yellow and green upon a blue ground. About the year 1451 the manufacture had become celebrated at Pesaro, the birthplace of Lucia della Robbia, who is regarded by some as the inventor of this ware. His Madonnas, Scripture subjects, figures, and architectural subjects are referred to by Mr. Marryat as "by far the finest works of art ever executed in pottery." The manufacture of majolica flourished during two centuries, under the patronage of the

house of Urbino, when the most eminent artists furnished designs. There is a tradition that Raffaelle was so employed, whence majolica sometimes passes as "Raffaelle ware." The most celebrated dates twenty years after the death of Raffaelle, but his scholars used his drawings in composing designs for the finest specimens. The manufacture attained its greatest celebrity between 1540 and 1560; the art then began to decline, and the introduction of porcelain—properly so called—helped to complete its downfall. Here we may mention that of late years, majolica, in England especially, has brought "fabulous prices." The Bernal collection, dispersed in 1855, contained about 400 pieces of majolica ware, which cost Mr. Bernal less than £1,000, but realised at the sale £7,000!

Majolica prospered in France under the name of *faience*, supposed to be derived from the village of Faience, in the department of Var, which, as early as the sixth century, was celebrated for glazed pottery. The *faience* manufacture flourished under the patronage of Catherine de Medici and her kinsman Louis Gonzaga; the latter established Italian artists, who produced enamelled pottery from native materials. This declined, but in the eighteenth century it recovered, and became celebrated for the brilliancy of a dark-blue enamel, with white patterns, upon a common ware. But the pottery peculiar to France is "Palissy ware," whose inventor had considerable difficulty in bringing his ware to perfection, though after sixteen years' labour he succeeded. His rustic pottery became the fashion of the day; his style is quaint and singular, his figures are chaste in form, the ornaments and subjects—historical, mythological, and allegorical—are in relief and coloured. His natural objects, except certain leaves, were moulded from Nature. His shells are from the Paris basin, his fish from the Seine, the reptiles and plants from the environs of Paris; the colours are unusually bright, and mostly confined to yellow, blue, and grey. He is "a great master of the power and effect of neutral tints." A favourite subject with him was a flat basin, or dish, representing the bottom of the sea, covered with fishes, shells, sea-weed, pebbles, snakes, etc.

France is also celebrated for its ware known as "Renaissance," or fine *faience* of Henri II., of which there are only twenty-seven pieces extant. The manufactory is conjectured to have been at Thouars, in Touraine. The material is fine white pipeclay, seen through a thin, transparent, yellow varnish; the patterns are engraved on the paste, the hollow being filled up with coloured paste, so as to resemble fine inlaying or chiselled silver work in *niello*. A single candlestick of this costly ware was sold some years ago for £220.

Holland, from its extensive trade with Japan, was induced to imitate Japanese porcelain. The chief seat of the manufacture was Delft, and the ware was known and esteemed in the sixteenth century by its fantastic design, good colour, and beautiful enamel. The Japanese origin was seen in the monstrous animals, the three-ringed bottle, the tall shapeless beaker, and the large circular dish, which were long regarded in Europe as favourite ornaments; while the common articles were so generally distributed as to obtain the name of "Delft ware,"—in Dutch, *plaled*. These, however, have been supplanted, even in Holland itself, by the superior manufactures of England, and the improvements introduced by Wedgwood in the making of pottery. About two hundred and fifty years ago, some Dutch potters established themselves in Lambeth; and, by degrees, a little colony was fixed in that village, possessed of about twenty manufactories, in which were made the glazed pottery and tiles consumed in London and other parts of the country. Here they continued to flourish till they were mostly superseded by the potteries of Staffordshire.

In England, the first manufactory of fine earthenware is said to have been erected in the reign of Elizabeth, at Stratford-le-Bow. This has long disappeared. The specimens preserved are remarkable for their lightness. The well-known Shakespeare jug—said to have belonged to our great dramatic poet—is a good specimen of Elizabethan pottery. It is of cream-coloured ware, divided lengthwise into compartments, each containing a mythological subject in high relief and of considerable merit. Fac-similes of this jug are made at Worcester. The Elizabethan pottery nearly approaches in hardness that of fine stoneware; it is dingy white, with quaint figures and foliage in relief. The Staffordshire potteries came into note in this reign; some of the earliest specimens are butter-pots of native brick-earth, glazed with powdered lead-ore, dusted on while the ware was in a green state.

In 1854 a manufactory of earthenware was established at Fulham, specimens of which are still valued by collectors as "Fulham ware," consisting of white *gorges* or pitchers, marbled porcelain vessels, statues, and figures. About the time of the Revolution, ale-jugs of native marl, ornamented with figures of white pipeclay, were introduced. During the reigns of Anne and George I., an improved ware was made of sand and pipeclay, coloured with oxide of copper and manganese, forming the well-known "agate-ware" and "tortoiseshell-ware," conferring on the pottery the character of a hard paste, which was subsequently so much improved by Wedgwood, and introduced under the name of "queen's-ware," by permission of Queen Charlotte. Previous to this period the upper classes of Great Britain obtained their porcelain from China; while the great bulk of the earthenware in domestic use was supplied by France, Germany, and Holland. To compete with these formidable rivals, Wedgwood, with persistent genius, employed the native materials which surrounded him in Staffordshire. He became a practical chemist, and improved the composition, glaze, and colour of his ware; and he invited Flaxman, the sculptor, and other eminent artists to furnish him with designs. Among Wedgwood's inventions are a terra-cotta resembling porphyry; basalt, or black ware, which would strike sparks like a flint; white porcelain, with properties similar to basalt; bamboo or cane-coloured biscuit, jasper; also a porcelain biscuit little inferior to agate in hardness, and used for pestles and mortars in the laboratories of chemists. He also imparted to hard pottery the vivid colours and brilliant glaze of porcelain. He reproduced with very great success some of the finest works of antiquity; he copied the Barberini or Portland vase, and, after executing fifty copies, destroyed the mould. His finest productions took rank with the choicest works of Dresden and Sèvres. He greatly improved stoneware, which France manufactured before the sixteenth century; and, in England, Dutch and German workmen were engaged in its manufacture at an early period. The mode of glazing by common salt enabled the stoneware manufacturers to compete successfully with delft and soft-paste fabrics. Next, a very fine unglazed stoneware, with raised ornaments, known as "red Japan ware," was made in England, after the failure of many previous attempts. It appears that two brothers from Nuremberg discovered, near Burslem, a bed of fine red clay, which they worked at a small factory erected on the bed itself. They endeavoured to conceal their discovery and their mode of working, but the process soon became known. Their ware was fine in material and sharp in execution, the ornaments being formed in copper moulds.

ANIMAL COMMERCIAL PRODUCTS.—XV.

PRODUCTS OF THE SUB-KINGDOM ANNULOSA

As for nearly a year the queen bee does not lay any eggs destined to become queens, if any evil befall her during that time the hive is left without a queen. Her loss or death stops the work of the hive, and, unless another queen is provided, the bees either join another hive or perish from inanition. After about two days, however, the bees generally decide to provide themselves with a queen, and this state of anarchy subsides. A few of the workers repair to the cells in which their eggs are deposited, three of these cells are made into one, a single egg being allowed to remain in it. When this egg is hatched, the maggot is fed with a peculiar nutritive food, called "royal bee bread," which is only given to maggots destined to produce queens. Work is now resumed over the whole hive, and goes on as briskly as before; on the sixteenth day the egg produces a queen, whose appearance is hailed with delight, and who at once assumes sovereignty over the hive.

If the old queen should survive, and the young queens emerge from the eggs last deposited by the old queen under ordinary circumstances, the workers do not allow them instant liberty, as severe battles would take place between them and the reigning queen; they are therefore kept prisoners in the cell, and fed through a small hole which is made in the ceiling of their cell, through which these captive queens thrust their tongues and receive their food from the workers. In this state of confinement the young queen bee utters a low complaining note

which has been compared to singing. When the old queen finds one of these captives, she uses every effort to tear open the cell and destroy her rival; the workers prevent this, pulling her away by the legs and wings. After repeated attempts to penetrate the cells and destroy her royal progeny, the old queen becomes infuriated, communicates her agitation to a portion of her subjects, who, together with her, rush out of the hive and seek a new home. The queen and accompanying swarm generally fly to some neighbouring resting-place, are observed by the owner, captured, placed in a new hive, and a new colony is at once commenced. The labourers that remain pay particular attention to the young imprisoned queens, and these, as they are freed from confinement, successively lead off fresh swarms, if the hive be not enlarged. Each swarm contains not only the recently-hatched young bees, but also a portion of the old inhabitants. After the hive has sent off three or four swarms, there are not enough bees left to guard the royal cells. The young queens consequently escape, two or three at a time; a battle ensues amongst them, and the strongest remains queen of the hive, after destroying all the royal larvæ and pupæ that remain.

According to Huber there are two varieties of working bees. The nurse-bees, which continue in the hive, whose office is to build the comb and feed the larvæ; and the collecting bees, which fly abroad and bring back to the hive the pollen and honey which they collect. This pollen is formed into little pellets, and packed on the hind legs in the receptacle formed there for this object. Honey is also swallowed by the bee, which passes into the crop, where it accumulates as in a reservoir, and on the return of the bee to the hive is poured into a honey cell. When a pollen-laden bee arrives at the hive, she puts her two hind legs into a cell, and brushes off the pellets with the intermediate pair. These pellets are kneaded into a paste at the bottom of the cell. The softened kneaded pollen thus packed away is called "bee-bread." Besides honey and pollen, bees collect a gum-resin called by Pliny *propolis*, principally from the balsamic buds of the horse-chestnut, birch, and poplar. This is used in closing up crevices in their hives, and in strengthening the margins of the cells of the comb.

Honey and *Wax* are two valuable commercial articles for which we are indebted to the labours of the hive bee. Bees'-wax is prepared by melting the comb in boiling water after the honey has been removed; the melted wax is then strained and cast into cakes, which have a pale-yellow colour and a pleasant odour.

White bees'-wax is formed by exposing the yellow wax in thin slices or ribands to light, air, and moisture, and then re-melting and forming it into cakes. Wax candles are made by suspending the wicks upon a hoop over a caldron of melted wax, which is successively poured over them from a ladle till they have acquired the proper size, so that the candle consists of a series of layers of wax; the upper end is then shaped and the lower cut off. Wax is also much used in taking casts or moulds, and as an ingredient in cerates and ointments. It is of great value in anatomy in representing normal or diseased structures. Most of our anatomical museums have instructive preparations made of this substance.

THE COCHINEAL INSECT (COCCUS CACTI).

In addition to the large amount of wax, the annual produce of our own hives, considerable quantities are received from Canada. Africa also sends us heavy supplies. About 100,000 lb. are annually shipped from Madras. Altogether the total annual importation of wax into the United Kingdom reached over 30,000 cwt. Above 2,000,000 lb. of honey are annually imported into the United Kingdom, in addition to that obtained from our own bee-hives.

Cochineal (*Coccus cacti*).—This valuable insect was first introduced into Europe in 1523 from Mexico. It belongs to the order *Hemiptera*, or half-winged insects.

The culture of the cochineal insect has extended from New to the Old World, and it is now produced in India, Java, Algiers, and many parts of Europe. The cochineal insect is small, rugose, and of a deep mulberry colour. It feeds on several species of cacti. These insects are scraped from the plants into bags, killed by boiling water, and then dried in the sun. Those are preferred which are plump, of a silvery appearance, and which yield when rubbed to powder a brilliant crimson. It is estimated that 70,000 of these minute insects are necessary to make a single pound of cochineal. In 1886 we imported 14,941 cwt. of cochineal, valued at £95,688.

The red colouring matters known by the names of *carmine* and *lake* are made from cochineal. Cochineal is used for dyeing scarlet, and is employed chiefly for woollen goods. The dye is obtained by fixing the colouring matter of the insect by a mordant of alumina and oxide of tin, and exalting the colour by the action of super-tartrate of potash.

THE ELECTRIC TELEGRAPH.—VI.

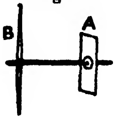
CONSTRUCTION OF SINGLE-NEEDLE INSTRUMENTS — THE COMMUTATOR — THE COIL — SWITCHES — SWISS COMMUTATOR—MODE OF JOINING UP CIRCUIT.

BESIDES the regular signals we have already enumerated, there are always a few others to denote various special things; but, as these do not form part of the universal code, and are occasionally varied, we need not insert them here, but may pass on at once to explain in detail the mechanism of the instrument itself.

This will easily be understood by reference to Fig. 23, which represents a back view of the interior of a single-needle telegraph instrument, the outer case being entirely removed. No alarum is shown here, that being frequently contained in a separate case; sometimes, however, for the sake of convenience, it is placed in the upper portion of the instrument-case, and even then it is quite distinct from the rest of it.

At the back of the base-board are seen four binding-screws, by which the instrument is joined in circuit with the batteries and the line. The wires leading from the positive and negative terminals of the battery are connected with two of these, marked respectively C and Z. The terminal L is connected with the line-wire, and E with the earth-plate.

Fig. 24.



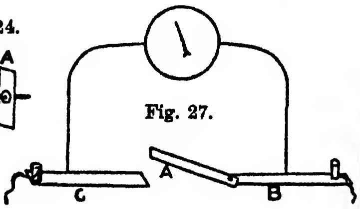


Fig. 27.

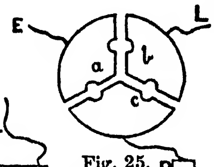


Fig. 25.

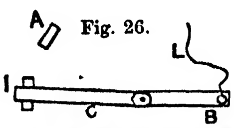


Fig. 26.

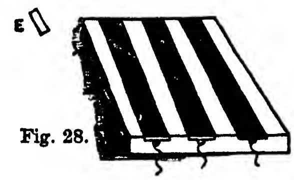


Fig. 28.

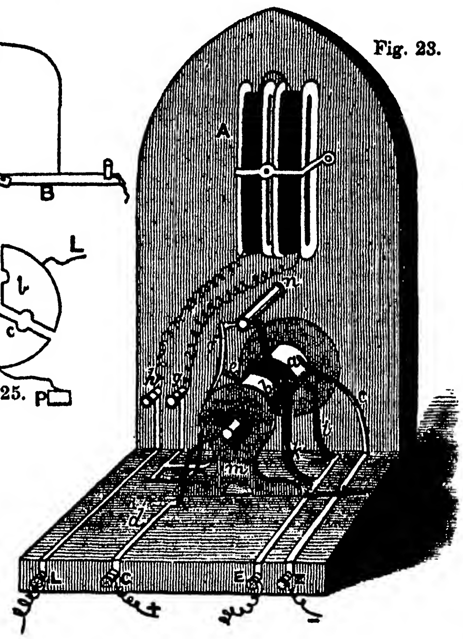


Fig. 23.

The handle seen on the face of the instrument is securely fastened to the cylinder, $a\,b$, of the commutator. This is made of some hard, dry wood, usually box, and is supported in front by the dial-plate, through which its axis passes, and at the back by the support M. In the figure it is shown in the position it occupies when the handle is pressed to the right, so as to send a beat in that direction. The barrel, or cylinder, has a metal ring at each end (a and b); these are perfectly insulated from one another by the dry wood between them. A brass spring, c, presses against the front one of these rings, and thus this end of the cylinder is in constant connection with the binding-screw Z, through the medium of this spring and the brass strip leading from it.

The other end of the cylinder is in metallic communication with the axle at that end of the cylinder, and thus, through the medium of the strip d and the spring which rises from it, with the binding-screw C. It will thus be seen that, by means of these springs, the two ends of the cylinder become virtually the two poles of the battery.

Two short pegs of stout wire are inserted in the metal rings of the cylinder—one in the under side of the front ring, and the other on the upper side of the back ring. These are so placed as to be in the same plane as the handle in front.

From E a strip of brass passes along the base, parallel with the cylinder, and is connected to a brass spring, k, so arranged that when the cylinder is inclined in that direction the pin e shall come in contact with the spring and raise it. A stout piece of brass, i, is likewise connected with the strip, and this serves as a stop for the pin in a to strike against.

On the other side of the instrument is a similar spring, f, and stop, but these are connected with the binding-screw g. The springs k and f, when not raised by the pin e, rest against the ends of a short piece of brass fastened to the support n, and thus are in metallic communication with one another.

This, then, is the transmitting part of the apparatus, and above the commutator is seen the coil A, which is essentially the receiving portion. In its construction this is very similar to the "detector" referred to in page 255, being merely a delicate galvanometer, with the needle placed vertically. Two small cases are made of thin wood or pasteboard, allowing just sufficient room for the needle to swing freely within them. They are then carefully wound round with very fine copper wire covered with silk, so as to insulate the successive layers. Considerable care is required in winding these coils, as if the wires in the different layers run at all crosswise much of the power is lost. Both coils are wound in the same direction, and the ends are then connected, so as to make one continuous circuit round both.

The reason for having two separate coils is that it renders it much more easy to put the needle in its place, one end of the axis being supported in the bearing seen behind the coils, while the other turns in a small hole in the bridge seen on the dial face. The construction of the needle is shown in Fig. 24, where A is the magnetised needle which is within the coil, and B that seen on the face of the instrument. The latter is usually unmagnetised, and serves merely as a pointer. In some instruments, however, both are magnetised, the poles being reversed so as to render the combination astatic. In either case the lower end is slightly weighted, so as to cause the needle to resume its vertical position immediately the current is interrupted. The needles are held in their places by means of small nuts on each side of them, screws being cut on the axis at the places where they are.

The ends of the coil are connected to the binding screws g and h, the latter being in communication with L by means of a brass strip.

We are now in a position to trace the course of the current through the instrument, and in doing so shall understand clearly the purpose served by the different springs and strips of which we have been speaking. First of all, we will suppose that a distant station is sending a message. In this case the batteries of the receiving station are not required, the only thing necessary being a direct path by which the current, as it arrives, may pass round the coils and on to the earth-plate. This we shall see is the case when the handle is vertical.

The current arrives by the line-wire, and reaches L; it then travels along the strip to h, traverses the coil, returning to g; from this it passes up the strip f, across the piece of wire against which this rests to k, and thence to E and the earth-plate. In this way the line-wire and the earth-plate are virtually connected directly to the ends of the coil, and for a simple receiving apparatus this is all that we need.

Now let us trace the course of the current when we send a message. Let us imagine the handle to be turned to the right, as shown in the illustration. The pin e first of all raises the

spring *f* off the support against which it leans, the other pin then comes in contact with *i*. The current now passes from C, along *d*, to the axis of the commutator, thence, by *e* and *f*, to the screw *g*. It then passes round the coils, and returns to *h*, whence it goes from L along the line-wire, round the coil of the instrument at the farther end, and back, by the earth, to E. The circuit is then completed by the stop *i*, the cylinder *a*, and the spring *c*.

When the cylinder is turned in the other direction, the course of the current is from C, by *d*, *e*, *k*, to the earth-plate, returning from L, by *h*, *g*, *a*, and *c*, to Z, so that now it passes round the coil in the reverse direction, and accordingly deflects the needle to the left instead of to the right.

When the instrument is not a terminal one, but in the middle of a circuit, L is usually connected with the line-wire on one side, and E on the other. A switch is, however, connected with the instrument, so that earth may be put on at either side at pleasure, and the instrument on that side is thus cut altogether out of the circuit.

Many different forms of switches are often employed for purposes similar to the above, and it is well, therefore, just to explain the principle on which they act. In Fig. 25 we have a figure of an ordinary peg switch, suitable for the case referred to. Three plates of brass are fixed upon a board in the manner there shown. One of these is placed in connection with the earth-plate, the other two with L and E respectively. If, then, we want to receive a message from L, we can cut off all stations on the other side by inserting a brass peg in the opening *a*, which will make a direct communication between E and the earth-plate. In a similar way we can cut off the stations on the other side by inserting the peg in *c*; while if it be necessary at any time to cut our own instrument altogether out of circuit, without interfering with other stations on the same line, we can easily do so by inserting the peg in *b*. In each case a much shorter path is provided for the current, and as it always travels along that which offers least resistance, it takes this in preference to the route through the instrument. When any instrument is by any such contrivance cut off from the rest, it is said to be "short circuited," and an arrangement of this kind is very frequently employed.

It not unfrequently happens that there are several different circuits between which communications are at times required to be made, and in this case the number or shape of the brass plates is altered so as to meet the special circumstances.

Another contrivance frequently employed for the same purpose is known as the "lever-switch," and will be understood from Fig. 26. The line-wire is connected to a binding-screw on a strip of brass, B. A second strip, C, turns on a pivot at the end of this, and can at pleasure be made to rest on the springs or studs, A, I, and E, which are connected respectively with the alarum, the instrument, and the earth-plate, or any other pieces of apparatus. The current may therefore be made to take either of these courses as may be desired, and the number of pegs may be increased if needed.

This switch is not so much employed as the peg-switch already described, since the number of combinations that can be effected by means of it is much more limited; it is, however, simple in construction, and less liable to be left wrong by accident.

In Fig. 27 we have a diagram showing the simplest form of short circuit that we can employ. The two wires are brought to binding-screws affixed to the brass strips B and C, and from these other wires lead to the instrument. Another strip of brass is attached by a pivot to B, so that when it rests on C a direct passage is provided for the current from B to C, but when in the position shown the current must pass through the instrument.

When there are several instruments in an office, and several different lines of telegraph starting from them, various arrangements of this kind are almost indispensable. Very frequently the different wires are brought to one part of the building, and connected there to a series of binding-screws, each of which is distinctly labelled.

When there are several different circuits, which have at times to be connected, the "Swiss Commutator," or "Universal Switch," represented in Fig. 28, is found a very useful contrivance. A flat slab of some hard, dry wood is taken, and strips of brass are inlaid on each side of it, those on the upper side running in the reverse direction to those on the lower. Holes are then drilled through these strips, as shown, and by inserting a spring brass peg in the proper one of these, a communication may be established between any one of the upper and any one of the lower circuits.

Many other contrivances of this nature are often employed, but we need not stop to refer to them in detail.

In our next lesson we shall describe a simpler form of commutator that is now adopted on many lines; but it will be best first to explain the method of joining up any circuit, that is, of making the proper connections with the batteries and line-wires. We will suppose that we have two stations with instruments, batteries, and line-wires all complete, and we want to establish the communication between them.

First of all, let each clerk connect the binding-screws L and E of his own instrument by means of a loop of wire, unless, as is frequently the case, there is an arrangement in the instrument for doing this by a short circuit. The battery wires are now connected to C and Z respectively; sometimes there is a difficulty in determining which is the proper wire for each screw, but this is easily obviated. We have merely to connect one wire to each screw, and then turn the handle in front of the instrument. If the connections are rightly made, the needle will move in the same direction as the handle is inclined. Should it move in the contrary direction, we at once know the wires are wrong, and have simply to reverse them.

The loop of wire is now taken off, and the line and earth wires joined on; the operator at the other end then sends a few deflections to the right, and we at once see if the wires have been rightly connected, and if they have not we reverse them. In this way all the connections are sure to be right; the main point to remember is that we first of all make sure our own batteries are rightly connected, and then afterwards see to the line-wires. Bearing this in mind will frequently save considerable trouble and loss of time.

NOTABLE INVENTIONS AND INVENTORS.

IX.—POTTERY AND PORCELAIN.

WE now come to porcelain, first produced in China, Japan, and Mexico. Bottles of Chinese manufacture have been found in the tombs of Thebes; one of them inscribed with the date between 1575 B.C. and 1289 B.C. Porcelain was common in the Chinese Empire 163 B.C., and in its greatest perfection 1000 A.D. The porcelain tower near Nankin was erected in 1400. This "vitreous, precious stone pagoda" was first built about A.D. 200, and rebuilt A.D. 1400, when it occupied nineteen years in construction, and cost £600,000. It was of nine storeys, though commonly reported thirteen, as it was intended to be of this number. Its height was 261 feet, and diameter at the base 96 feet 10 inches. There were in it 150 bells, and 140 lamps. In 1856, Tien Wang, one of the rebel chiefs, wantonly blew up the pagoda with gunpowder, some say to spite another Wang; others, because he declared it to be too old; the fragments of this remarkable edifice were left on the spot, and were carried away by the curious.

> "So much for monuments that have forgotten
> Their very record."—*Byron.*

Marco Polo describes the manufacture in China during the thirteenth century. When specimens found their way to Europe, the Portuguese were so struck with the resemblance between the texture of this fine ware, and that of the cowry-shells, or *porcellana*, as they were called, that they imagined the ware might be made of such shells, or of a composition resembling them, and named it accordingly. They imported numerous and splendid collections into Europe, where it was called "china" from the country which produced it. The Dutch next established a traffic with India and Japan, and Europe was long supplied with porcelain through Holland. The English next shared in the trade, through the East India Company. In Queen Anne's reign china collections became a passion. Fokien now produced the pure white porcelain of china; Nankin the blue and white and pale buff porcelain; and King-te-ching the old sea-green and crackle porcelain. The ancient crackle is so much esteemed in Japan that £300 has been paid for a single specimen. The Chinese call this ware snake porcelain. The

egg-shell porcelain is much prized in China; it is coloured citron-yellow for the exclusive use of the Emperor, and ruby for the use of the Imperial family. An inferior porcelain, known as Indian china, is made at Canton. Chinese porcelain is of beautiful material and delicate texture, brilliant colour, and pure glaze; but the forms and design are so hideous, that it has been said the vase of the humblest Greek potter of the best period has an æsthetic value far surpassing the most costly productions of the Celestial Empire. ("Encyclopædia Britannica.")

The first successful imitation of Chinese porcelain produced in Europe was by Böttcher, an apothecary's assistant, at Berlin; but he was suspected of practising the black art, and so escaped to Dresden, where, under the patronage of the Elector of Saxony, Augustus II., he made some vessels much resembling Oriental porcelain, from a brown clay found near Meissen, with a reddish tint. To preserve his secret, the Elector sent him to the fortress of Königstein, on the Elbe, where a laboratory was prepared for him. In 1707 he returned to Meissen. Böttcher hitherto produced only a kind of red and white stoneware, but in 1709 he succeeded in producing a white porcelain, which led Augustus to establish a manufactory at Meissen, and to appoint Böttcher the director. He employed the kaolin of Aue in the Erzebirge for his porcelain, the secret of which was kept for some time. This kaolin powder was conveyed in sealed barrels, and all persons in the factory were sworn to secrecy. No visitor was admitted, the oath to the workmen was renewed every month, and when the king was allowed to enter the factory, a similar obligation was imposed on him. In each room was set up the motto, in large letters, "Be secret unto death." At length, just before the death of Böttcher in 1719, a foreman escaped from the factory to Vienna, where he submitted to be bribed, and rival factories soon sprang up in different parts of Germany. Among the finest Meissen ware are groups from antique models, figures in lace dresses, flowers studied from Nature, and vases of honey-comb china.

The first rival of Meissen was the porcelain factory of Vienna, established in 1720, but its porcelain holds a lower rank than that of Dresden or Berlin; it is remarkable for its raised and gilded work, and reliefs of solid platinum and gold. Next, at Höchst, on the Nidda, arose a celebrated pottery, the director of which carried his recipes about with him, but of which he was plundered, and the secret sold; hence originated the porcelain factories of Switzerland, of the Lower Rhine, and even of Cassel and of Berlin. The Fürstenburg works, in the Duchy of Brunswick, originated in a bribe offered by one of the dukes to a Höchst workman. The ware of the factory of Nymphenberg, in Bavaria, is much esteemed, many of the designs being from the celebrated picture-gallery of Munich. The porcelain factory of Berlin was not very successful until the fradulent transference of the best of the workpeople and the *matériel* of the Meissen factory. The Berlin porcelain was but an imitation of the Dresden, but it yielded the King an annual revenue of 200,000 crowns. The Prince-Bishop of Fulda established a factory in a house adjoining the episcopal palace, but it failed through the dignitaries of the church claiming the privilege of carrying off specimens without paying for them. The porcelain factories of Thuringia originated about 1758, when the son of a chemist experimented on some sand which he had bought of an old woman, and obtained by its means a porcelain-like substance, which led to the erection of a factory at Sitzerode, sanctioned by the Prince of Schwarzburg. The abundance of fuel supplied by the forests of Thuringia led to the erection of several other factories, all which produced porcelain still prized by collectors. A factory established by the Empress Elizabeth, in 1756, near St. Petersburg, still produces good porcelain from native materials. Denmark has also a factory at Copenhagen, and Switzerland one at Zurich.

Meanwhile, England had been striving in the porcelain manufacture. The Bow works, closed in 1762, have been already mentioned. The mark is a crescent or *bow;* it is scarce, but never fine. This and the Chelsea were soft wares, made from a mixture of white clay, white sand from Alum Bay, and pounded glass. The Chelsea works, in an old mansion by the Thames bank (of which we have seen a view upon a fine Chelsea vase) did not flourish until George II. imported workmen, models, and materials from Brunswick and Saxony. The best period of Chelsea porcelain was between 1750 and 1755, when such was the demand for it that dealers flocked to the works, and at the doors purchased pieces as soon as they were fired. A service sent as a royal present cost £1,200. The finest works were in the style of the best German; the colours fine and vivid, and the claret colour peculiar.

At the Chelsea ovens, the celebrated Dr. Johnson, who had conceived the notion that he was possessed of a secret for making porcelain, obtained permission to have his compositions baked here, where he watched them day by day; he was not allowed to enter the mixing-room, and roughly modelled his composition in a room by himself. He failed, for none of the articles he formed would bear the heat of firing. He conceived that one simple ingredient was sufficient to form the body of porcelain; whereas, the manager of the factory declared that in the composition of the Chelsea paste no less than sixteen different substances were blended together. The Chelsea works were discontinued in 1764, when the manufacture was removed to Derby, and the ware was called Chelsea-Derby. It has the mark of a D, crossed by an anchor; it is very beautiful, but dear as silver. Nearly opposite Chelsea were the Battersea enamel works, at York House, where Ravenet and others drew for Alderman Jansen, but the factory was soon closed.

The Derby factory was established in 1750, and became most famous by the junction of the Chelsea artists already named. Flaxman designed for the establishment. The Worcester works were established in 1751, by Dr. Wall and some others. They first imitated blue and white Nankin china; they afterwards adopted the Sèvres style, with the Dresden method of painting. At these works was first used the Cornish stone, or kaolin, discovered in 1768. Shropshire has long been famous for its porcelain factories. In 1772, at Caughley, near Broseley, was established the factory, chiefly for blue and white, and blue, white, and gold porcelain, known as Salopian ware. At Coalport, earthenware is made similar to the Etrurian or Wedgwood ware, of which we have already spoken. The Staffordshire works are concluded to be of Roman origin, evident remains of Roman potteries having been repeatedly discovered at a considerable depth below the present surface. The county is unrivalled in amount of production of pottery. Early in the present century good porcelain was made at Nantgarrow and Swansea; it is also stated that the Bristol china, a white ware, formerly common in the west of England, was made in Wales, and sold in Bristol. At the Rockingham works, in 1837, was completed for William IV. a superb dessert service of 200 pieces of porcelain, painted with 700 subjects; it had occupied five years, and cost upwards of 3,000 guineas. From the same works we have seen a fac-simile of a small Roman jug, dug up at Caistor, in Lincolnshire, of which the ground-colour was red, with raised ornamentation of fern leaves of darker red.

The first establishment in France was formed in the castle of Vincennes, whence, in 1756, it was transferred to Sèvres. In 1760, Louis XV., at the solicitation of Madame de Pompadour, bought up the establishment. The factory became celebrated for its soft porcelain, or *pâte tendre;* but the great object was to produce the hard porcelain, which had rendered Saxony the envy of Europe. Then kaolin was not known in France, nor was its presence suspected until, about 1768, the wife of a surgeon, near Limoges, noticed there a white unctuous earth, which she tried to use as an economical substitute in her house for soap. Her husband showed a portion of the earth to an apothecary at Bordeaux, who, being aware of the search making for kaolin, sent a specimen of the Limoges earth to the chemist Macquer, who at once recognised it as the desired kaolin. He then established the manufacture of hard porcelain at Sèvres, in 1766. In form the Sèvres china is not equal to the Dresden. Such was its profuseness of decoration that a law was passed in 1769, and renewed in 1784, limiting the use of gold in the decoration of porcelain at the royal manufactory at Sèvres, which accounts for the rarity of the old French gilded porcelain. This being a royal establishment, all Sèvres porcelain had on its under surface an initial mark in blue, surmounted with the French crown.

In Italy a factory was established at Deccia, near Florence, early in the last century. Venice also manufactured porcelain, until 1812; but the most famous manufactory in Italy is the

Capo di Monti, at Naples, founded by Charles III., in 1736. This sovereign appears to have exceeded the royal amateurs of Europe in his cultivation of the ceramic art, and he even surpassed Augustus III., who was nicknamed by Frederick of Prussia "the Porcelain King," from his having exchanged a whole regiment of dragoons for some huge useless china vases. Charles III. even worked in the factory with his own hands, and held an annual fair in front of the royal palace at Naples, where was a shop for the sale of the royal productions; and there was no more certain road to the king's favour than in becoming a purchaser. When Charles became King of Spain, he founded a factory at Madrid, which was destroyed by the French in 1812. His successor, Ferdinand, sanctioned the erection of other porcelain works, and even allowed the royal workmen to assist in their formation; they appear to have robbed the parent factory of its gold and silver models and other valuables.

The porcelain of Capo di Monti was not, as is commonly the case, an imitation of the art of some rival factory. Its beauty and excellence are due to the design, from shells, corals, embossed figures, etc., artistically moulded in high relief. Mr. Marryat regards the tea and coffee services of this ware as perhaps the most beautiful porcelain articles ever produced in Europe for transparency, thinness of the paste, elegance of form, and gracefully twined serpent handles; as also for the delicate modelling of the ornamental groups in high relief, painted and gilt, contrasting well with the plain ground. Its manufacture was conducted with the greatest secrecy. The modelled figures of Capo di Monti ware are very life-like; whole scenes are wrought, all in one dull tint of stone, with nothing but the modelling to attract us. Nothing has ever been produced so life-like. If one could be quite sure as to the extent of the firing which they have undergone, it would be difficult to praise them too highly.

The prices paid for very fine porcelain are necessarily high. A Sèvres service of a good period has cost 30,000 livres. Mr. Minton received £1,000 for his service of turquoise and parian; the Marquis of Hertford gave £1,000 for two vases; and Lord Ward £1,500 for a dessert service of Sèvres. In the Bulteel collection of rare old porcelain, lately sold, were an old Chelsea vase and cover, which brought 355 guineas; an Oriental enamelled cistern, 295 guineas; old Sèvres cups and saucers, and plateaux, from 50 to 221 guineas; old Sèvres cabarets, 375 to 535 guineas; a pair of old Sèvres vases, 765 and 660 guineas; and three old Sèvres vases, 1,350 guineas. Such works as these belong, however, rather to the fine arts than the useful arts. A better taste has, however, grown more evident in pottery and porcelain in every-day use, as the people have become more familiar with the beautiful forms of antiquity, and art schools have been established, hence jugs sold for a few pence each are even of classic forms. The barbarous style of ornament, too, brought from China, has been superseded, the old "willow pattern" has descended from the dining-room to the kitchen, and a true taste for classic ornamentation is extensively cherished. The choice vessels of Etruria, Herculaneum, and Pompeii are imitated in Staffordshire, with copies of Roman pottery introduced into England more than two thousand years since. In articles of ornament we become familiarised with some of the finest works of Greek art, of which almost every chimney-piece bears evidence; whilst the grotesque vulgarities which delighted our forefathers are supplanted by fac-similes of sculptural triumphs that have been and will continue the admiration of ages.

The Porcelain Rock of China is situated in the King-te-chin district, where the Chinese have made nearly all their porcelain for about 3,000 years. The rock is reduced to powder, and made into bricks of two kinds, one being called "kaolin," and the other "petuntse," the supposed equivalent of Cornish china stone. The British porcelain clay, kaolin, exists as a soft imperfectly-formed variety of granite, and the china-stone, "petuntse," is a more talcose rock.

The porcelain clay used in English works is obtained in Cornwall, and shipped in large quantities. The shipments in the year 1869 comprised 105,700 tons of kaolin, commonly called china clay; and 28,500 tons of china stone. Devonshire produced 56,200 tons of clay in 1869. 60,210 tons of clay were exported from Poole in the year, one-third of it for London, and nearly another third for America; the total being 2,000 tons more than in the preceding years.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—VI.

To construct a semi-elliptical arch, of which A B *is the span, and* C D *the height* (Fig. 56).

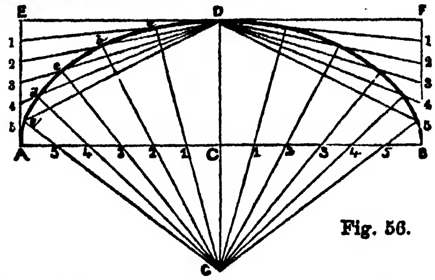


Fig. 56.

Divide C A and C B into any number of equal parts.

Divide A E and B F into a corresponding number of equal parts.

Number the parts as in the figure.

Produce D C, and make C G equal to C D.

From D draw lines to the points 1, 2, 3, 4, 5, in the lines E A and F B.

From G draw lines through the points 1, 2, etc., in the line A B, and produce these lines until they cut those of corresponding numbers drawn from D to the points in the lines E A and F B.

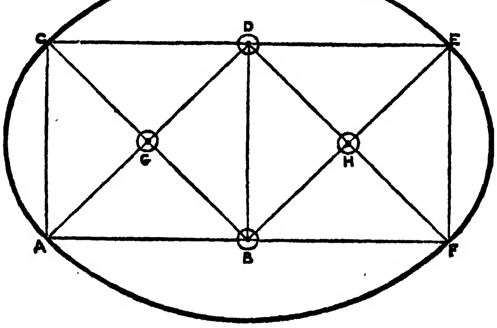
Thus—G 1	will cut	D 1 in *a*.
G 2	,,	D 2 in *b*.
G 3	,,	D 3 in *c*.
G 4	,,	D 4 in *d*.
G 5	,,	D 5 in *e*.

The curve is to be drawn through these intersections.

Strictly speaking, no portion of an ellipse is a part of a circle, and the curve cannot therefore be drawn with compasses so as to be mathematically correct; but there are many ways in which figures nearly approximating to ellipses may be drawn by arcs of circles; and among these the following is given:—

To construct an elliptical figure by means of two squares, A B D C, B D E F (Fig. 57).

Fig. 57.



Draw diagonals in each of the squares, intersecting each other in G and H.

From B, with radius B C, describe the arc C E.

From D, with the same radius, describe the arc A F.

From G, with radius G C, describe the arc C A.

From H, with the same radius, describe the arc E F, which will complete the figure.

THE SPIRAL.

The *spiral* is a curve, which makes one or more revolutions round a fixed point, but does not return to itself.

To construct a spiral of one revolution (Fig. 58).

Describe a circle, using the widest limit of the spiral as a radius, as A XII.

Divide the circle into any number of equal parts, as I to XII, and draw radii.

Divide one of these radii, as A XII, into a corresponding number of equal parts, as 1 to 12.

From the centre, with radius A 1, describe an arc cutting the radius I in B. From the centre, continue to describe arcs from points 2, 3, etc., cutting the corresponding radii II, III, etc., in the points C, D, E, F, G, H, I, J, K, L.

From XII trace a curve passing through all these points, which will be an Archimedes' spiral of one revolution.

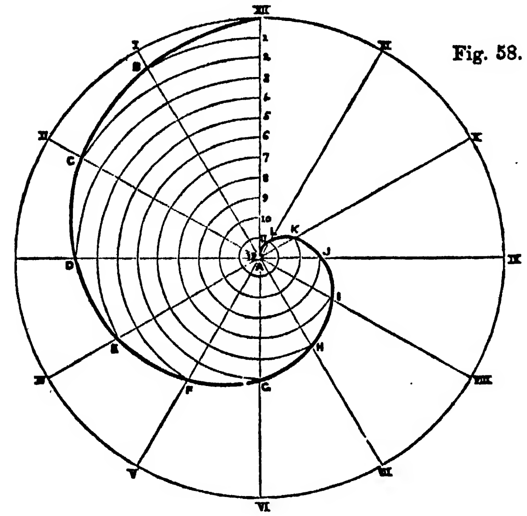


Fig. 58.

It will interest our students to learn that Archimedes, the most celebrated of ancient mathematicians, was born at Syracuse, B.C. 287. He cultivated particularly the branches of science relating to the areas of curves and sections of curved surfaces. He proved that the area of a circle is equal to half the rectangle contained by its circumference and radius, and showed how to approximate, as near as may be required, to the quadrature of a circle. The spiral was invented by Conon, but its properties having been demonstrated by Archimedes, it is in honour of him called by his name.

To describe a spiral of any number of revolutions—in this case three (Fig. 59).

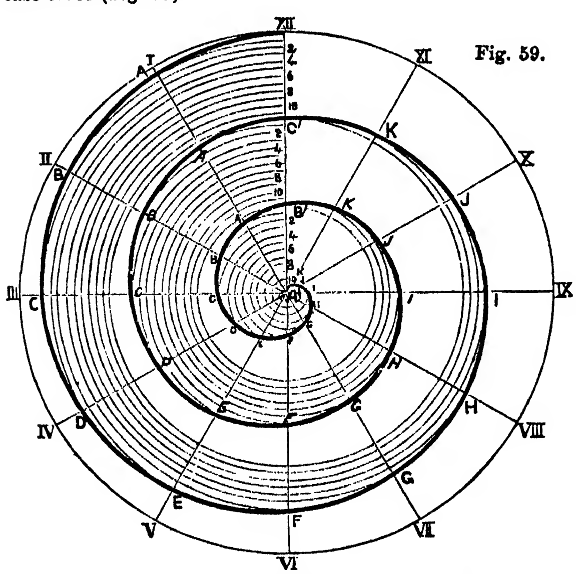


Fig. 59.

Divide the circle into any number of equal parts, as I to XII, and draw radii.

Divide one of the radii, as A XII, into a number of equal parts, A' B' C', corresponding with the required number of revolutions.

Divide each of these into the same number of equal parts as there are radii—viz., 1 to 12.

It will be evident that the figure consists of three separate spirals—one from XII to C', another from C' to B', and another from B' to A'.

Commence, as in the former spiral of one revolution (Fig. 58), by drawing arcs from the points 1, 2, 3, etc., to the correspondingly numbered radii, thus obtaining the points marked with the largest capitals; and the first revolution having been brought up to C', proceed in the same manner to draw arcs from the points 1, 2, 3, etc., contained between B' and C', cutting the corresponding radii in the points marked with the italic capitals, and draw the curve through these points, thus reaching B'.

Proceed in the same manner to draw arcs from the points between B' and A', thus obtaining the points marked with the smallest capitals, and the spiral may then be brought up to the centre.

To describe a spiral adapted for the volute of an Ionic column, by means of quadrants (Fig. 60).

Divide the given height into eight equal parts.

From 3 and 4, draw lines at right angles to A B.

Between these two lines describe a circle (the eye of the

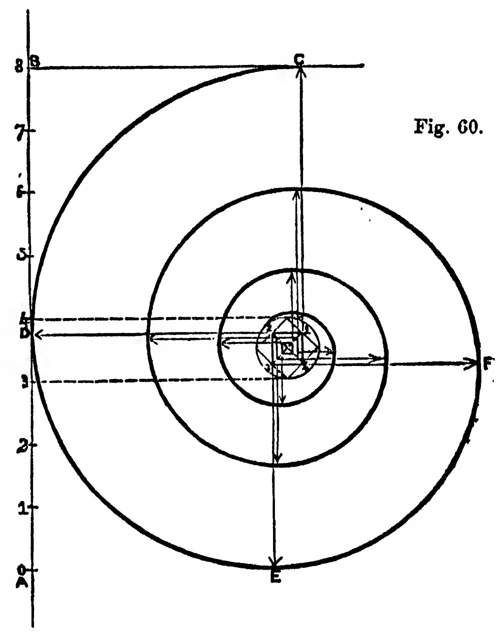


Fig. 60.

volute), the centre being at a distance from A B equal to four of the divisions. Inscribe a square in this circle. Bisect the sides of this square, join the bisecting points, and thus a smaller square will be inscribed in it.

Divide each of the semi-diagonals into three equal parts, join these points, and two more squares will be formed within the former one.

The quadrants are drawn in rotation from the angles of each square, commencing at 1 with radius 1 C.

The next is drawn from 2 with radius 2 D.
The next " 3 " 3 E.
The next " 4 " 4 F.

The process is then continued from the inner squares.

THE INVOLUTE (Fig. 61).

If a perfectly flexible line is supposed to be wound round any curve, so as to coincide with it, and kept stretched as it is gradually unwound, the end of, or any point in the line will describe or trace another curve, called the *involute* of the curve —being in reality the opening out, or *unrolling*, of the periphery of the first curved surface.

Thus, if a circular piece of wood were fastened on a board, and a string equal to the circumference fastened by one end to it and rolled round it, a pencil placed in a loop in the end of the string would, as the string is gradually unrolled, trace the involute.

The circle (or other original curve) is called the *evolute*.

To construct the involute of the circle A (Fig. 61).

Divide the circle into any number of equal parts (1 to 12), and draw radii.

Draw lines (tangents) at right angles to these radii.

On the tangent to radius No. 1, set off a space equal to one of the parts into which the circle is divided; and on each of the tangents set off the number of parts corresponding to the number of the radius. Tangent No. 12 will then be the circum-

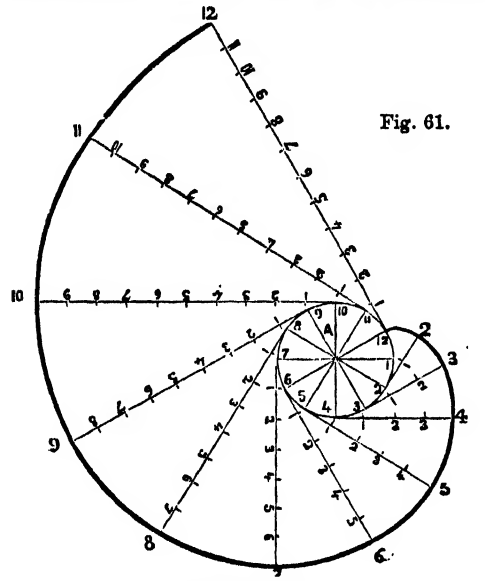


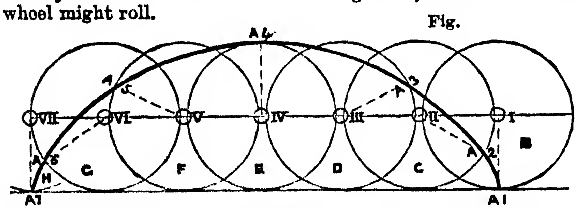
Fig. 61.

ference of the circle unrolled, and the curve drawn through the extremities of the other tangents will be the involute.

THE CYCLOID (Fig. 62).

If a mark were to be made with chalk on the iron tire of a wheel at the exact spot where it touches the ground, the white mark, as the wheel rolls along a level road, would be observed to move in a peculiar form, which is called the "cycloid" curve; whilst the centre of the nave of the wheel (I), although moving onward, would travel in a horizontal line, that is, it would keep exactly the same distance from the ground, however far the wheel might roll.

Fig.



When the wheel is at B, its centre is at I, and the point A is at A 1.

When the wheel has moved to C, the centre will be at II, and the point A will be at A 2.

When the wheel has moved on to D, the centre will be at III, and the point A will be at A 3.

When the wheel has moved on to E, the centre will be at IV, and the point A will be directly over it, viz., at A 4.

When the wheel has moved on to F, the centre will be at V, and the point A will be at A 5.

When the wheel has moved to G, the centre will be at VI, and the point A will be at A 6.

When the wheel has moved on to H, the centre will be at VII, and the point A will be at A 7.

It will thus be clearly seen that the wheel in moving from A 1 to A 7 has passed completely through one revolution, and therefore that the length of the line A 1 to A 7 is equal to the circumference of the circle laid out on a straight line.

The straight line on which the wheel rolls is called the *director*. The wheel is called the *generating circle*, and the point A is called the *generator*.

VEGETABLE COMMERCIAL PRODUCTS.—XII.

(*b*) VOLATILE OR ESSENTIAL OILS.

THESE oils occur in the stems, leaves, flowers, and fruits of most sweet-scented plants, whence they are obtained by distillation. In this respect they differ from the oils already described, which are found only in the seed, obtained by expression from the same, and do not evaporate; hence the latter have been called fixed oils. The difference between fixed and volatile oils is easily shown. A drop of any fixed oil—such as olive oil, for instance—leaves a stain on paper which is permanent; but a drop of any volatile or essential oil—as, for example, oil of bergamot—makes a similar stain, which evaporates and disappears.

To obtain essential oils, the leaves, flowers, or other parts of the plant are put into an apparatus for distillation. This always consists of a boiler in which the vapour is raised, and a condenser in which it again becomes fluid. For distillation on a small scale, a common retort and receiver answer every purpose, care being taken to keep the receiver cool, by placing it in cold water. When the water boils, the steam passes through the retort into the condenser, where it is re-converted into water, the essential oil floating on its surface; this is skimmed off, and afterwards purified by filtering. But the perfume of most flowers depends on the presence of a fragrant volatile or essential oil, peculiar to the plant. When, therefore, we obtain this oil, we really get the essence of the plant, or the essential principle which makes it valuable; and although the plant may be an annual, and perish, together with its fragrance, in a few weeks or months, yet, if we extract the oil, we can retain the essence of the plant as long as we please. The following are the most important of the essential oils which occur in commerce:—

OIL OF LAVENDER, from *Lavandula spicata*, L.; natural order, *Labiatæ*.—Large quantities are raised at Mitcham, in Surrey; but it is also imported from France and Germany.

OIL OF THYME, from *Thymus vulgaris*, L.; natural order, *Labiatæ*.—This oil is distilled from all parts of the plant. It comes into this country from Hamburg and from the United States. It is used in scenting Windsor soap.

OIL OF PEPPERMINT, from *Mentha piperita*, L.; natural order, *Labiatæ*.—Besides that raised and manufactured at home, we receive large quantities from Germany and the United States.

OIL OF ANISE, from *Pimpinella anisum*, L.; natural order, *Umbelliferæ*.—This plant is a native of the Levant, whence a great deal of the anise of commerce is derived. It is also much cultivated in France, Naples, and Germany—particularly in Thuringia and Swabia. We receive considerable importations from Germany and the East Indies; but those sorts coming from Spain, Apulia, and Malta, are considered in commerce to be the most valuable.

OIL OF CARAWAY, from *Carum carui*, L.; natural order, *Umbelliferæ*.—The best caraway oil comes from Malta, Naples, and Alicante in Spain. Small quantities are received from Germany. Much more, however, is home-manufactured and exported.

Cinnamon, clove, cassia, and pimento yield essential oils, to which reference has already been made in treating of those species; oil of bergamot, oil of lemons, and Neroli oil, or oil of orange flowers, have also been mentioned in connection with those fruits.

OIL OF ROSES, ATTAR OF ROSES, or OTTO OF ROSES, is distilled from the petals of *Rosa centifolia*, L., *Rosa gallica*, L., and numerous other species of rose. The attar of roses is prepared in Persia and other Asiatic countries; but, with all the aids of science, the process still remains unknown to Europeans. Some idea of its costliness may be gathered from the fact that 100,000 roses must be distilled to yield 180 grains, or three drachms of pure attar. Five guineas have often been paid for one ounce of this essence. It is the favourite perfume of the civilised world, and in the East is a most essential luxury. In Cashmere the harvest of rose leaves is celebrated as the festival of the year. Its description is well known in the exquisite poetry of Moore.

III. TINCTORIAL PLANTS, OR PLANTS FURNISHING VALUABLE DYES.

The clothing which is furnished by the textile plants and the sheep's wool would be of one dull uniform hue, if it were not for the valuable dyes furnished by the tinctorial plants. At first the colours of plants, when transferred to clothing, imparted

only a temporary beauty; for the art of fixing them, or uniting them permanently with the cloth, by means of mordants, was unknown; but by experiments long and carefully conducted, Nature has been interrogated successfully, and we are now able to render these colours fast, or permanent, thus enriching our silken, woollen, linen, and cotton manufactures with an almost endless variety of beautifully-coloured designs. It is impossible to mention even the names of the numerous plants which furnish materials for the dyer. Only a few, and those the most common in the commercial world, can be noticed. All the parts of plants furnish these dyes; sometimes it is the root, or the wood of the stem; sometimes the leaves, flower, or fruit.

ALKANET ROOT (*Anchusa tinctoria*, L.; natural order, *Boraginaceæ*).—A perennial herbaceous plant, with rough, oblong, lanceolate leaves, a stem about a foot in height, purplish flowers, and a long woody root, with a deep red bark. It is a native of the Levant, and is much cultivated in Germany and the south of France, particularly about Montpellier, for the sake of the red colouring matter contained in the bark of the root, easily obtained by soaking the root in alcohol or oil. It is used for colouring ointments red, especially lip-salves; it is also employed as a dye, to colour gun-stocks and furniture in imitation of rosewood. Alkanet root comes to this country in packages, weighing about two cwt. each, chiefly from Germany and France. About eight to ten tons are annually imported.

SUMACH (*Rhus coriaria*, L.; natural order, *Anacardiaceæ*).—The sumach of commerce is the crushed or ground leaves of this plant, imported from Sicily. This material is valuable for tanning light-coloured leather, and imparts a beautiful bright-coloured yellow dye to cottons, which is rendered permanent by proper mordants. In 1886, 13,083 tons of sumach were imported into the United Kingdom.

ARNOTTO (*Bixa orellana*, L.; natural order, *Flacourtiaceæ*).—This is a small evergreen tree, indigenous to tropical America, and now cultivated in the East Indies. It is called *Roucon* by the French, and the Orleans tree by the Germans. The first South American settlers noticed the brilliant and showy colour obtained from its berries, on the bodies of the Indians, by whom it is called *bixa* or *bija*, and not only used it themselves, but speedily converted it into an article of commerce. The arnotto tree grows about twelve feet in height; its leaves are smooth and heart-shaped, and its pink-coloured flowers are followed by oblong bristled pods, somewhat resembling those of the chestnut, at first rose-coloured, but changing as they ripen to dark-brown. On bursting open, these pods show in their interior a splendid crimson farina or pulp, in which are contained ten or twelve seeds, in colour somewhat resembling coral beads. The arnotto of commerce is prepared from this crimson pulp. By maceration in hot water the seeds are separated from the pulp, which is then made into balls or cakes of two or three pounds' weight; these, when dry, are wrapped up in large leaves, and packed in casks for exportation. Another kind—the roll arnotto—is of a much superior quality. It is a hard extract, and contains a much greater proportion of colouring matter.

Good arnotto is of the colour of fire, bright within, soft to the touch, and dissolves entirely in water. It is used in Holland for colouring butter, and in Cheshire and Gloucestershire for dyeing cheese (under the name of cheese-colouring), to which it gives the required tinge, without imparting any unpleasant flavour or unwholesome quality. Flag or cake arnotto comes from the West Indies, especially from the island of St. Domingo or Hayti. Roll arnotto is principally brought from the Brazils. The rolls are small, not exceeding two or three ounces in weight. Arnotto is also used to dye silks and cottons, especially to form the colour called aurora. It is much to be regretted that the beautiful orange and gold-coloured dyes yielded by this plant are fugitive, and become discoloured in the sun. The bark of the arnotto tree makes good ropes, available in the West Indies for common plantation uses. It is not uncommon to find that tropical trees are capable of being put to a wide variety of uses.

MYROBALANS (*Terminalia chebula*, L.; natural order, *Combretaceæ*).—This dye is obtained from a small tree indigenous to British India, and closely allied to the myrtle. All the species of *Terminalia* have astringent properties. The fruit and galls of this tree are very astringent, and much valued both by dyers and tanners. The fruit is about the size of a date, pointed at the ends, and of a yellowish brown. The myrobalans of commerce are probably derived from more than one species. With alum they give a durable yellow colour. Myrobalans are now an important item in our commerce with India. We receive them from Calcutta and Bombay. The average annual imports exceed 600,000 cwt.

SAFFLOWER (*Carthamus tinctorius*, L.; natural order, *Compositæ*).—This plant furnishes a beautiful rose colour, which is used for silks, cottons, and the manufacture of rouge. Safflower is an annual herbaceous plant, somewhat resembling a thistle, to which it is allied. The leaves are ovate-lanceolate, somewhat spinous, alternate, sessile; flowers yellow.

The safflower is a native of the Levant, and is cultivated in China, India, and in the south of Europe. The dye is obtained from the florets. These are gathered, pressed into little cakes, dried, and then packed in strong bales, weighing about 2 cwt. each. As found in commerce, these cakes consist of flaky masses of a red colour, intermixed with yellow filaments, the former tint being due to the corolla, and the latter to the stamens. The flowers thus contain two colouring principles, one yellow, soluble in water, and the other rose-red, called carthamine, or carthamic acid, soluble in alkaline solutions; this latter, when precipitated from its solution, dried, and mixed with finely powdered talc, constitutes rouge. It is the carthamic acid which renders the safflower valuable as a dye. The greater portion of the safflower imported into England comes from Persia, Egypt, and the East Indies.

LOGWOOD (*Hæmatoxylon campeachianum*, L.; natural order, *Leguminosæ*).—A middle-sized tree with a contorted trunk, rarely more than one foot and a half in diameter, covered with ash-coloured bark; branches crooked, beset with sharp thorns; leaves pinnate or somewhat bi-pinnate, with sub-cordate leaflets; flowers yellow, in terminal racemes.

This tree, indigenous to Central America, Mexico, and Campeachy, has been introduced into the West Indies, and is now naturalised there. The heart-wood is the part of the tree employed; the generic name refers to its blood-red colour. Logwood is of very frequent use in the arts, as it forms the basis of many of the reds in printing calicoes, and is esteemed one of the best deep-red dyes. It is imported in logs, which are cut up into chips and ground to powder, for the use of dyers, hatters, and printers, in powerful mills constructed for that purpose. Logwood, when boiled, communicates its own dark-red colour to the water, and the addition of a few drops of acetic acid changes the colour to a bright red. Red ink is made in this way, a little alum being added to render the colour permanent. If, instead of an acid, an alkali—such as soda or potash—be added, the colour changes to a dark blue or purple, and with a little management every shade of these colours may be obtained. Logwood is so hard and heavy as to sink in water. It is used chiefly for dyeing red, blue, and black. We import every year about 40,000 tons from South America, whence a great deal also goes to Spain, France, and Germany. The principal ports for the reception of logwood are London, Cadiz, Bordeaux, and Hamburg.

MADDER (*Rubia tinctoria*, L.; natural order, *Rubiaceæ*).—A small, herbaceous, perennial creeping plant; stems slender, quadrangular; leaves four in a whorl; flowers small; fruit yellow; berry double, one being abortive.

Madder is cultivated in France, Southern Europe, and the Levant, where it is indigenous, for the sake of the valuable red dye furnished by the root. The roots are dug up when the plant is about three years old, carefully dried, and packed into bags or bales for exportation. As found in commerce, madder root is in long cylindrical pieces, about the thickness of a quill, and of a deep red or brown colour. If ground before exportation, the powder is sent in very large casks. We get madder roots whole from India, Turkey, Greece, Spain, and France; and ground from Holland and Germany. Powdered madder root is a bright Turkey red, but, by the addition of suitable chemicals, every shade of red, purplish-brown, purple, lilac, and even a lively rose colour can be obtained from it. Madder root imparts its red colour to water and alcohol. It is used as a basis for red dyes, as it affords a tint which, when properly fixed by appropriate mordants, is not affected by light or moisture. Scarcely a calico or muslin print is made without the aid of madder root, in some way or other, for forming the pattern.

The imports of madder, madder-root, garancine, and munjeet into the United Kingdom in 1886 were 21,395 cwt.

PRINCIPLES OF DESIGN.—X.

ART FURNITURE (*continued*).

By Christopher Dresser, Ph.D., F.L.S., etc.

In my last chapter I gave, in an axiomatic form, those principles which should guide us in the construction of works of furniture, and there endeavoured to impress the necessity of using wood in that manner which is most natural—that is, "working" it with the grain (the manner in which we can most easily work it), and in that way which shall secure the greatest amount of strength with the least expenditure of material. I again invite my readers to consider these matters, for they lie at the very root of the successful construction of furniture. If the legs of chairs, or their seat-frames, or the ends or backs of couches, are formed of wood cut across the grain, they must either be thick and clumsy, or weak; but, besides this, the rightly constituted mind can only receive pleasure from the contemplation of works which are wisely formed. Daily contact with ill-shaped objects may have more or less deadened our senses, so that we are not so readily offended by deformity and error as we might be; yet, happily for us, directly we seek to separate truth from error, the beautiful from the deformed, reason assists the judgment, and we soon learn to feel when we are in the presence of the beautiful or in contact with the degraded.

My illustrations, given some in this chapter and some in the last, in page 313, will show how I think chairs should be constructed. Fig. 19 is essentially bad, although it has traditional sanction, hence I pass it over without further comment. Fig. 23 is in the manner of an Egyptian chair. It serves to show the careful way in which the Egyptians constructed their works. The curved rails against which the back would rest are the only parts which are not thoroughly correct and satisfactory in a wood structure. Were the curved back members metal, the curvature would be desirable and legitimate. The back of this chair has immense strength (the backs of some of *our* chairs are of the very weakest), and as a whole it is a seat which would, if well made, endure for centuries. Fig. 20 is a chair of my own designing, in which I have sought to give strength to the back by connecting its upper portion with a strong cross-rail of the frame.

Fig. 21 is a chair slightly altered from one in Mr. Eastlake's work on "Household Furniture;" as shown in our illustration, it is a correctly formed work. Fig. 22 is an arm-chair in the Greek style, which I have designed. Fig. 26 is a lady's chair in the Gothic style. Fig 25 (p. 313), a lady's chair in early Greek. These I have prepared to show different modes of structure; if the legs are fitted to a frame (the seat-frame), as in the early Greek chair just alluded to, they should be very short, as in this instance, or they must be connected by a frame below the seat, as in Fig. 27. The best general structure is that in which the front legs pass to the level of the upper surface of the seat.

Fig. 27 is a copy of a chair shown by Messrs. Gillow & Co., of Oxford Street, in the Paris International Exhibition of 1867. In many respects it is admirably constructed. The skeleton brackets holding the back to the seat are a very desirable adjunct to light chairs; so are the brackets connecting the legs with the seat-frame, which strengthen the entire chair. The manner in which the upper rail of the back passes through the side uprights and is "pinned" is good. The chief, and only important, fault in this chair is the bending of the back legs, involving their being cut against the grain of the wood.

Fig. 28 is a chair from Mr. Talbert's very excellent work on "Gothic Furniture." It shows an admirable method of supporting the back. Fig. 24 (p. 313) I have designed as a high-backed lounging-chair. With the view of giving strength to the back, I have extended the seat and arranged a support from this extension to the upper back-rail, and this extension of the seat I have supported by a fifth leg. There is no reason whatever why a chair should have four legs. If three would be better, or five, or any other number, let us use what would be best. In my drawing, the stuffing of the back has been accidentally shown somewhat too rounded. This does not in any way interfere, however, with what I have in view—viz., the illustration of a particular structure or formation of chair.

I have now given several illustrations of modes of forming chairs. I might have given many more, but it is not my duty to try and exhaust a subject. What I have to do is simply to point out principles, and call attention to facts. It is the reader who must think for himself—first, of the principles and facts which I adduce; secondly, of the illustrations which I give; thirdly, of other works which he may meet with; and fourthly, of

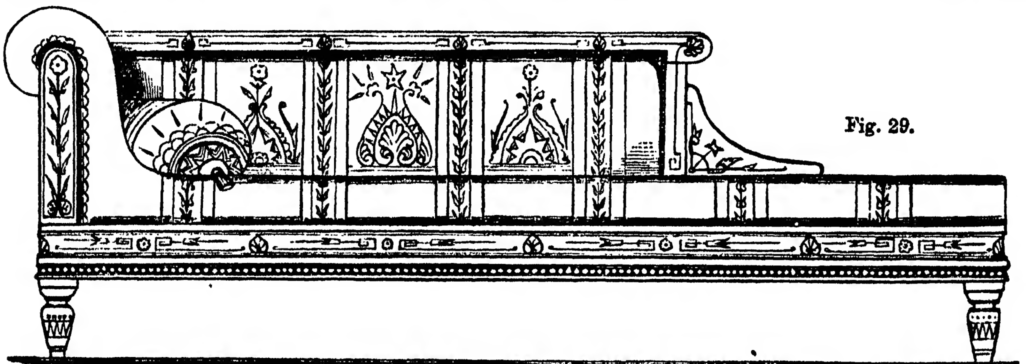


Fig. 29.

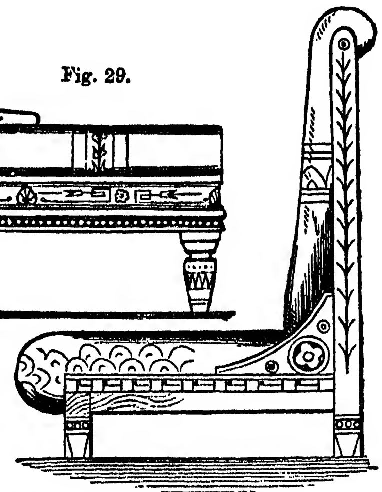


Fig. 26.

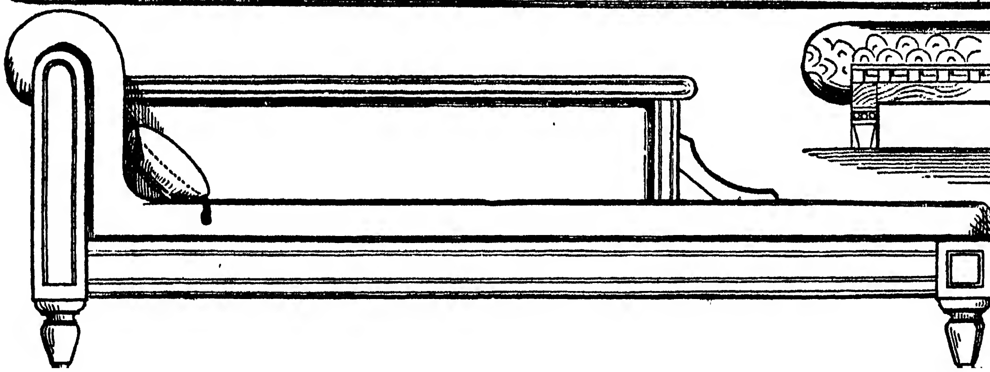


Fig. 30.

further means of producing desirable and satisfactory results besides those set forth in my illustrations.

As it cannot be doubted that a well-constructed work, however plain or simple it may be, gives satisfaction to those who behold it—while a work of the most elaborate character fails to satisfy if badly constructed—we shall give a few further illustrations of structure for other articles of furniture besides chairs, which have become necessary to our mode of life.

lateral pressure, but would not bear quite the same amount of pressure from above. The latter, however, could bear more weight than would ever be required of it, and would be the more durable piece of furniture.

Fig. 31 gives a legitimate formation for a settee; the cutting-out, or hollowing, of the sides of the legs is not carried to an extreme, but leaves a sufficiency of strong wood with an upright grain to resist all the pressure that would be placed on the

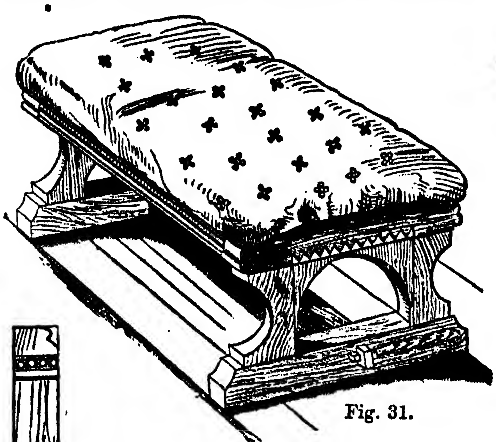


Fig. 31.

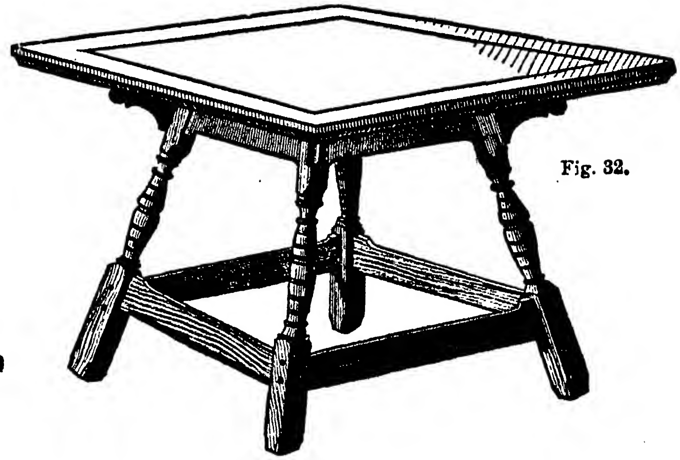


Fig. 32.

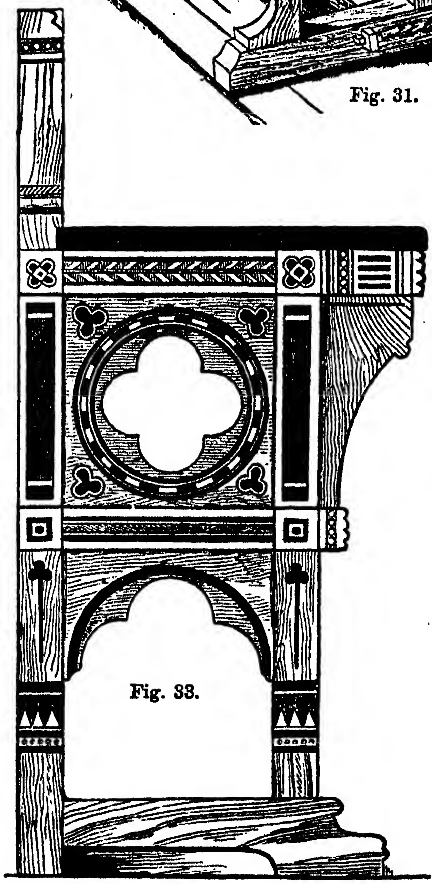


Fig. 33.

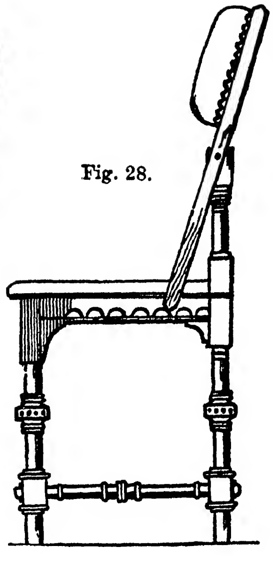


Fig. 28.

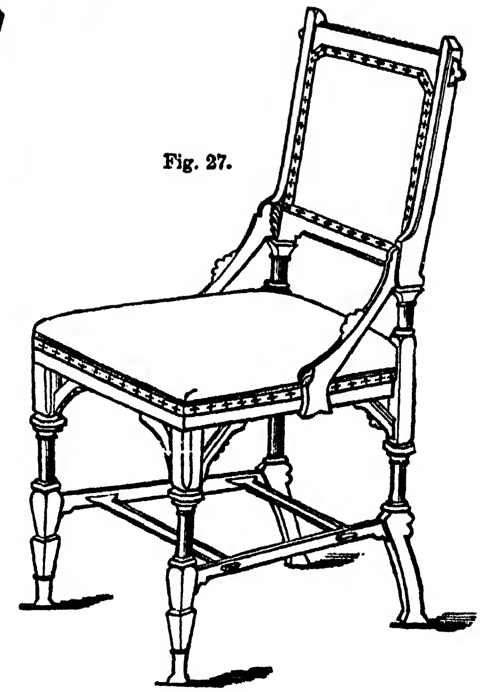


Fig. 27.

Fig. 29 is one of my sketches for Greek furniture, designed for Moor Hall. It was formed of black wood. Here the frame of the seat is first formed, and the legs are inserted beneath it, and let into it, while the wood-work of the end of the couch stands upon it, being inserted into it. This appears to have been the general method with the Greeks of forming their furniture, yet it is not so correct structurally as Fig. 30, another of my sketches, where the end and the leg are formed of one piece of wood. The first formation (that of Fig. 29) would bear any amount of pressure from above, but it is not well calculated for resisting lateral pressure; while the latter would resist this

seat, and the lower and upper thickened portions of the legs act as the brackets beneath the seat in Fig. 23 (p. 313). This illustration is also from Mr. Talbert's work. Fig. 32 is a table slightly altered (structurally improved, I think) from one in Mr. Eastlake's work. I see no objection to the legs leaning inwards at the top; indeed, we have here a picturesque and useful table of legitimate formation. Fig. 33 is the end elevation of a sideboard from Mr. Talbert's work. Mark the simplicity of the structure. The leading or structural lines are straight and obvious. Although Mr. Talbert is not always right, yet his book is well worthy of the most careful con-

sideration and study; and this I can truly say, that it compares favourably with all other works on furniture with which I am acquainted.

The general want which we perceive in modern furniture is simplicity of structure and truthfulness of construction. If persons would but think out the easiest mode of constructing a work before they commence to design it, and would be content with this simplicity of structure, we should have very different furniture from what we have. Think first of what is wanted, then of the material at command.

ELECTRICAL ENGINEERING.—XIII.

BY EDWARD A. O'KEEFFE, B.E., A.S.T.E.,

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THE CENTIMETRE-GRAMME-SECOND SYSTEM OF UNITS—CONVERSION OF ELECTRICAL INTO MECHANICAL ENERGY AND HEAT.

THE system of units now universally used is the centimetre-gramme-second or C.G.S. system, and in terms of the three quantities—length, mass, and time—all physical quantities, such as velocity, work, current, etc., can be expressed.

The unit of length is the *centimetre* = ·3937 inch.
The unit of mass is the *gramme* = 15·432 grains.
The unit of time is the *second.*

From these three fundamental units the following are derived:—

Velocity.—The unit of velocity is the velocity of a body which moves at the rate of one centimetre per second.

Acceleration.—The unit of acceleration is that acceleration which, acting on a body for one second, imparts to it unit velocity. (In the subsequent approximate calculation the acceleration due to gravity will be taken as 981 centimetres per second; this being approximately the velocity per second, which gravity imparts to a falling body.)

Force.—The unit of force (which is called the *dyne*) is that force which, acting on a mass of one gramme for one second, imparts to it a velocity of one centimetre per second.

Work.—The unit of work (which is called the *erg*) is the work done in overcoming a force of one dyne through a distance of one centimetre.

Heat.—The unit of heat (which is called the *calorie*) is the quantity of heat required to raise a mass of one gramme of water from 0° to 1°C. It is equal to 42,000,000 ergs.

Unit of quantity.—If two charges of electricity of the same kind are placed close together, they repel one another according to a definite law. The force of this repulsion will be directly proportional to the product of the two charges, and inversely proportional to the square of the distance between them. This law, due to Coulomb, can be best expressed in symbols. Let f = the force of repulsion, q_1 and q_2 the two charges, and d the distance between them; then

$$f = \frac{q_1 \times q_2}{d^2}.$$

If d is one centimetre, f one dyne, and $q_1 = q_2$, we obtain a definition for unit quantity of electricity in terms of the fundamental units. Unit quantity of electricity is, then, *that quantity which when placed in air at a distance of one centimetre from a similar and equal quantity repels it with a force of one dyne.*

Potential.—A definite force of repulsion is exercised between any two similarly charged bodies A and B, when placed in any positions. Considering A as fixed, if B is moved closer to A, an amount of work must be done equal to the product of the distance moved, multiplied by the average force of repulsion between them. As B is moved up to A, this force increases from nothing—when an infinite distance separates them, up to a maximum—when a minimum distance separates them. In moving up from the infinite distance to any fixed position, work must be expended on B to overcome the electrostatic repulsion, but this work is not lost. If B be allowed to move from that fixed position to an infinite distance, under the action of the repulsive force, it can be made to do an amount of work exactly equal to that which was expended on it in moving it up to the fixed position. In other words, when in the fixed position the body B has *potential* energy stored up, which is the equivalent of the work done on it; it possesses potential energy or energy due to its position. If B contains unit quantity of electricity, we can measure the amount of work that must be done on it to bring it up to any position, and that quantity of work gives a measure of the potential at that point. *The potential at any point* can be therefore defined as *the amount of work that must be expended on unit quantity of positive electricity in bringing it up to that point from an infinite distance.* It follows from this, that the difference of potential between two points is the amount of work that must be done in moving a unit of positive electricity from one point to the other, and is clearly independent of the path along which the unit moves. *Unit difference of potential* (or of *electromotive force*) *exists between two points when it requires the expenditure of one erg to move a unit of positive electricity from one point to the other.*

Unit current.—Unit current is that current which is caused by the passage of unit quantity in one second. The volt, which is the practical unit of electromotive force, is equal to 100,000,000 absolute C.G.S. units.

The ampère, which is the practical unit of current, is equal to $\frac{1}{10}$th of the absolute C.G.S. unit.

∴ The ohm, which is the practical unit of resistance, is equal to 1,000,000,000 absolute C.G.S. units.

With those data we are in a position to calculate the work in horse-power which is being expended in any circuit when we know the current and the E.M.F. used in it.

CONVERSION OF ELECTRICAL INTO MECHANICAL ENERGY.

Let V_1 and V_2 be the potentials at the two points in the circuit between which we require to know the rate at which work is being expended;

Let C denote the current flowing in the circuit;

Let E denote the E.M.F., driving the current between the two points;

Then $E = V_1 - V_2$ = the work in ergs done on *one* unit of positive electricity in moving from one point to the other:

∴ EQ = the work done on Q units in moving them from one point to the other;

but according to the above definition of current,

$Q = CT$ where t = time in seconds during which the current has been flowing.

Substituting this value for Q.

ECT = work in ergs expended in t seconds by the current C and an E.M.F. of E.

∴ EC = work in ergs expended in one second by the current C and E.M.F. E.

The rate at which work is being done is thus found, but all the terms are expressed in absolute units. In order to reduce them to the practical units generally used—the volt, ampère, and horse-power, the following modifications must be made:—

E must be multiplied by 100,000,000 to reduce it to volts;
C must be divided by 10 to reduce it to ampères;
therefore the left-hand side of the equation becomes

$EC \times 10,000,000$ = work in ergs per second;

if E = 1 volt and C = 1 ampère, then clearly their product, one volt-ampère, = 10,000,000 ergs per second.

This is called a *watt.*

To reduce ergs to foot-pounds.

Referring to the definitions, gravity exerts a pull on a mass of one gramme of 981 dynes,

and one erg = one dyne × 1 centimetre;

∴ the work done in raising one gramme through a height of 1 centimetre = 981 ergs,

but 1 foot = 30·48 centimetres,
1 pound = 453·6 grammes.

∴ the work done in raising one pound through a height of one foot = 981 × 30·48 × 453·6 ergs,

or one foot-pound = 13,560,000 ergs.

but one H.P. (horse-power) $= 33{,}000$ foot-lbs. per minute.
$= 550$ foot-lbs. per second.

$\therefore$ one H.P. $= 7{,}460{,}000{,}000$ ergs per second.

$$\therefore \quad E\,C \times 10{,}000{,}000 = \text{H.P.} \times 7{,}460{,}000{,}000.$$

$$\therefore \quad \text{H.P.} = \frac{E\,C \times 10{,}000{,}000}{7{,}460{,}000{,}000}, \text{ or H.P.} = \frac{E\,C}{746}.$$

The rule, then, for finding the horse-power expended in any portion of a circuit is to *multiply the* E.M.F. (in volts) *by the current* (in ampères), *and divide by* 746.

Two instruments—an ampère-meter and a volt-meter—are all that is necessary to find the rate at which work is being done, or the energy expended in the circuit. This must not be confused with the total work done; it is simply *the rate at which energy is expended,* and must be multiplied by the time in minutes during which the current has been flowing in order to give total work done.

In arc lighting, the efficiency of a lamp is usually spoken of in terms of candle-power per horse-power expended in the lamp, in which case efficiency $= \dfrac{\textit{Candle-power} \times 746}{E\,C}$.

But in incandescent lighting the *watt* is more often used as the unit of energy, in which case efficiency $= \dfrac{\textit{Candle-power}}{E\,C}$.

In both these cases C denotes the current in ampères, and E the electromotive force in volts.

The formula for the H.P. in any circuit can be expressed in the three forms depending on the truth of Ohm's Law:—

$$\text{(I.)} \quad \text{H.P.} = \frac{E\,C}{746}; \text{ but } E = CR.$$

$$\text{(II.)} \quad \text{H.P.} = \frac{C^2 R}{746}; \text{ or } C = \frac{E}{R}.$$

$$\text{(III.)} \quad \text{H.P.} = \frac{E^2}{R \times 746},$$

No. I. being used when both E.M.F. and current are known; No. II. being used when both current and resistance are known; No. III. being used when both E.M.F. and resistance are known.

CONVERSION OF ELECTRICAL ENERGY INTO HEAT.

Taking the equation,

$$E\,C \times 10{,}000{,}000 = \text{work in ergs per second,}$$

and from the definition of heat,

$$1 \text{ calorie} = 42{,}000{,}000 \text{ ergs,}$$

$$\therefore \quad \frac{E\,C \times 10{,}000{,}000}{42{,}000{,}000} = \text{the heat in calories generated per second by a current C and an E.M.F. E.}$$

$$\text{(I.) or HEAT (in calories per second)} = \frac{E\,C}{4 \cdot 2}, \text{ where E is in volts, and C is in ampères.}$$

This equation can also be written in forms

$$\text{(II.) HEAT (in calories)} = \frac{E\,C\,t}{4 \cdot 2}.$$

$$\text{(III.) HEAT (in calories)} = \frac{C^2 R\,t}{4 \cdot 2}.$$

$$\text{(IV.) HEAT (in calories)} = \frac{E^2\,t}{R \times 4 \cdot 2}.$$

Where t is the time in seconds during which the current has been flowing.

Of these four equations, No. (I.) shows the *rate at which heat is being generated* in the circuit; Nos. (II.), (III.), and (IV.) show the *total amount of heat generated* in the time t.

EFFICIENCY OF AN INCANDESCENT LAMP.

In order to measure the efficiency of an incandescent lamp, a modification of Rumford's photometer may be conveniently used (Fig. 30).

H is a wooden clip holding the wires that carry the current to the lamp, E. A is an ampère-meter to measure the current, and V is a volt-meter to measure the E.M.F. used in E. G G is a scale on which slides a holder containing a standard candle, C. At the other end of the apparatus is a sheet of white paper before which is fixed a pencil, which throws two shadows on the paper, R and S, due to the two sources of light. The candle is moved along the scale till these shadows are equally dark.

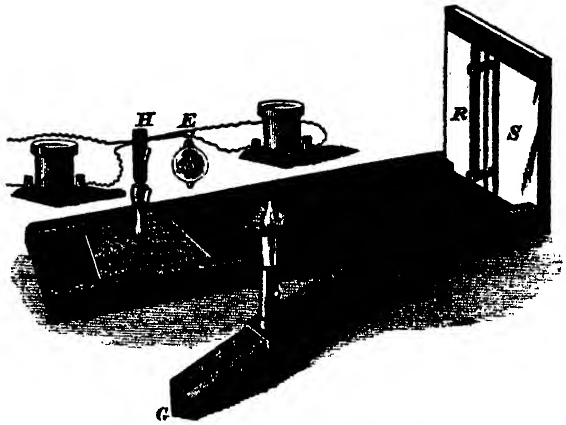


Fig. 30.—RUMFORD'S PHOTOMETER.

Let d_1 be the distance of the lamp from the paper.
„ d_2 „ „ „ candle „ „

Then efficiency $= \dfrac{d_1^2}{d_2^2\,E\,C}$ where C = current and E = E.M.F.

TECHNICAL DRAWING.—XXIV.

DRAWING FOR MACHINISTS AND ENGINEERS.

TOOTHED WHEELS (*continued*).

FIG. 235.—*System composed of a rack driving a pinion.* Here the curves of the faces of the teeth in the rack are portions of a cycloid generated by the circle A, the diameter of which is half that of the pitch-circle B, rolling on the pitch-line C D.

In commencing this study, draw the pitch-line, and a perpendicular, on which set off the centre of the pitch-circle and the generating circle.

Draw both of these circles, the tangent point being at T.

Set off the length of the pitch along the rack and on the pitch-circle, and proceed to divide each pitch into a tooth and a space.

Now describe the cycloid which is to give the face of the teeth of the rack. If the drawing be large, or one from which a "pattern" is to be made, this cycloid may be cut in thin wood so as to form a templet (described in a previous lesson), and with this the faces of the teeth of the rack may be described; but for general use in smaller drawings the curve may be an arc of a circle, the radius of which is the length of the pitch, as shown at G H.

The flanks of the teeth of the rack are perpendiculars, and are strengthened by being joined by quadrants to the line parallel to the pitch-line, which forms the root of the teeth.

The curve of the faces of the teeth of the pinion are portions of the *involute* of the pitch-circle.

For a full description of the nature of this curve, and the method of describing it, the student is referred to Lesson VI. in "Practical Geometry applied to Linear Drawing."

Fig. 236 will remind the student of the general principles of its construction.

Let A B be a portion of the circle from which the curve is to be evolved, divided into a number of equal parts; as, 1, 2, 3, 4, 5, 6.

At these points draw radii, and draw tangents to each.

From the points of tangent set off on these lines divisions corresponding to the figure from which each is drawn. Thus, on tangent 1 set off *one* of the divisions, from tangent No. 2 set off *two*, and so on, and through the points so obtained the involute is to be drawn. Here, again, for general purposes in drawing, the arc of a circle is substituted for the true curve, and it will be seen that the arc struck with a radius equal to a pitch corresponds nearly (though not perfectly) with the curve shown at B (Fig. 236).

The flanks of the teeth are radial, turned off into the inner circle by small arcs.

The remaining portion of the pinion will be easily completed without further explanation. The space at K, as the student will no doubt know, is the *key-bed*, in which a key is placed to fasten the pinion on the journal or end of the shaft.

being taken as equal, the radius of the pins is therefore one quarter of the pitch.

The spaces in the pinion are struck with the same radius. The curve of the faces of the teeth is, as has already been said, a portion of the epicycloid; but an arc drawn from A, the middle of a pitch, so nearly coincides with the curve B C, which is the curve properly constructed, that in drawings it is usually substituted for it.

Fig. 236.

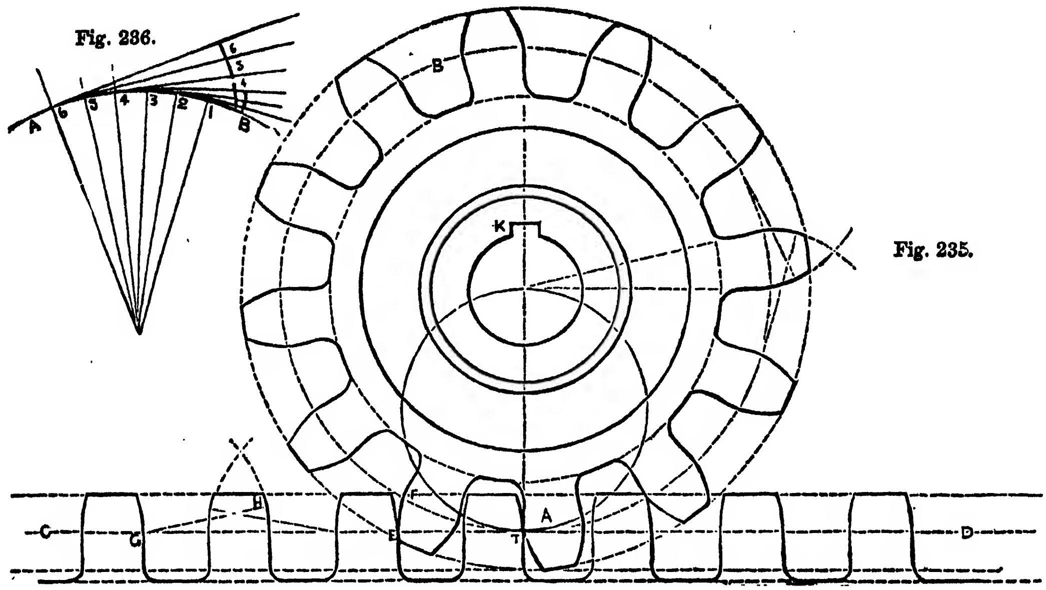


Fig. 235.

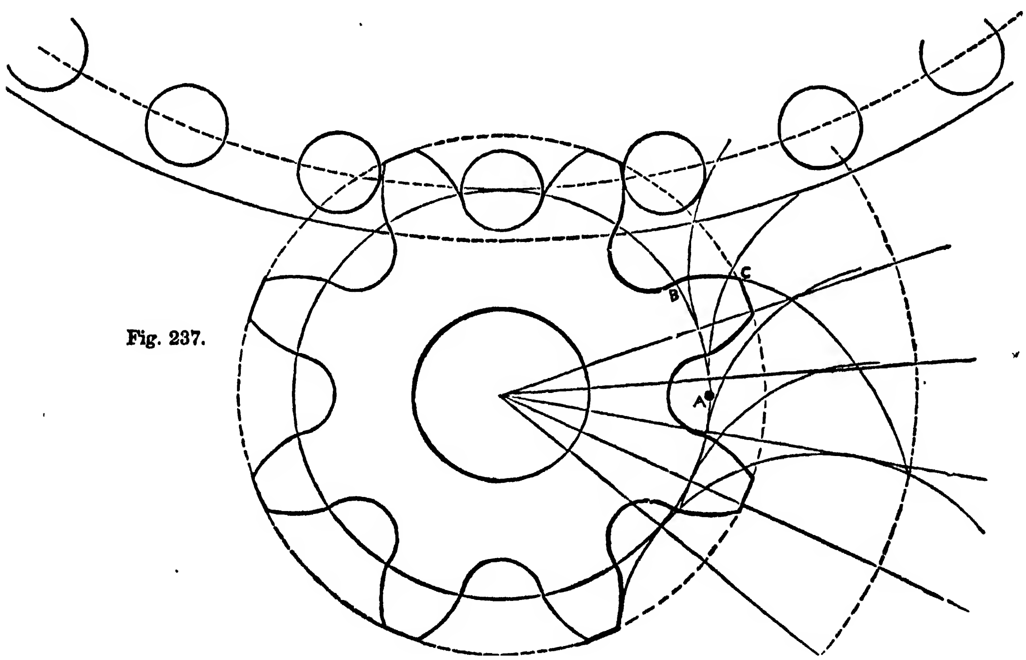


Fig. 237.

Fig. 237.—In the system here shown, the pinion drives a wheel with pins instead of teeth, and the face of the tooth of the driver is a portion of the epicycloid curve generated by a circle of half the circumference of the wheel.

In copying this example, the pitch-circles of driver and follower having been described, and the pitches having been set off on each, the circles representing the pins are to be drawn. The spaces and diameter of the pins in this instance

The following important remarks on the teeth of wheels are made by Professor Goodeve :—

"It will be proved, when we treat of rolling curves, that the surface of one tooth must always slide upon that of another in contact with it, except at the moment when the point of contact is passing the line of centres.

"This matter should be well understood. The teeth are perpetually rubbing and grinding against each other; we cannot prevent their doing so; our rules only enable us so to shape the acting surfaces, that the pitch-circles shall roll upon each other.

"Nothing has been said about the teeth rolling upon each other. It is the pitch-circles that roll; the teeth themselves slide and rub during every part of the action which takes place out of the line of centres.

"Since, then, the friction of the teeth is unavoidable, it only remains to reduce it as much as possible, which will be effected by keeping the arc of action of two teeth within reasonable limits.

"Generally, the friction before a tooth passes the line of centres is more injurious than that which occurs after the tooth has passed the same line. The difference between drawing a walking-stick along the ground after you, and pushing it before you, is given by Mr. Denison as an illustration of the difference between the friction before and after the line of centres; but this difference is less appreciable when the arc of contact is not excessive."

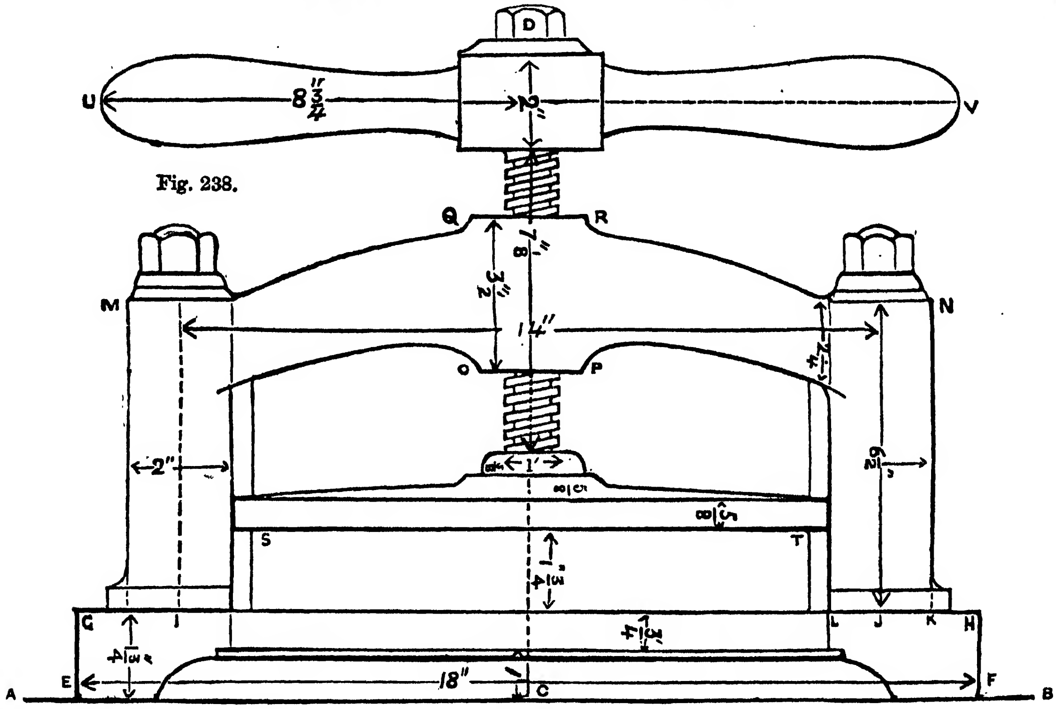


Fig. 238.

MECHANICAL DRAWING FROM ROUGH SKETCHES.

In the previous figures the student has been allowed to copy the examples by measurement, or to increase their sizes as he may think proper.

By such means, however, only practice in *copying* ready-made drawings is obtained, and such practice must only be taken as the means to the end—certainly not as the result to be attained; for a draughtsman who can but copy is, indeed, little better than a machine; being merely capable of measuring accurately and drawing fine lines, most of the latter result being due to his instruments, he thus becomes, in the true sense of the term, a "mechanical draughtsman."

It is to avoid this that the course here laid down blends mental study with manual practice, and in the present section an endeavour is made to afford the student practice in working from rough sketches, such as are made in an off-hand manner by the engineer, and entrusted to the occupants of the drawing-office to work out.

These sketches, though approximately correct in *general* proportions, are not drawn to any absolute scale; *the student must not, therefore, trust to measuring from them.* The true measurements are, however, marked on each part, and the student is to take these from his scale. He is advised to work Fig. 238 (which is a rough hand-sketch of a small copying-press) to a scale of not less than $\frac{3}{8}$ of an inch to an inch.

To make this scale, draw a straight line, and on it set off a number of divisions of $\frac{3}{8}$ of an inch each. Mark the beginning of the line O, the first division 1, the second 2, and so on; these divisions will then represent inches. This plan is better than measuring direct from the foot-rule, as it avoids the necessity of calculating how many inches so many times $\frac{3}{8}$ make, by which errors often occur.

Now divide one of the above spaces into eighths for measuring the fractional parts of inches.

The scale being thus prepared, draw the base-line, A B, and the central perpendicular, C D.

Next mark off 9″ on each side of C—viz., C E and C F—the length of the base being 18″.

Draw perpendiculars indefinitely high at E and F; mark off on one of these $1\frac{3}{4}$ inch—viz., E G. It is not necessary to measure this height on *both* perpendiculars, for by placing the T-square against G, the line G H will give the height of F H.

On each side of the centre line now set off 7″, and erect the perpendiculars I and J for the centre lines for the standards; the width from centre to centre being 14″.

On each side of I and J set off J K, draw the lines K, L (and corresponding lines on the opposite side), and draw the horizontal M N at $6\frac{1}{2}''$ above G H.

Now draw the horizontal O P at $5\frac{1}{2}''$ above G H, and Q R at ' above it; the width of O P is $2\frac{1}{4}''$, and of Q R $2\frac{1}{2}''$. The arches are then to be drawn from centres on the perpendicular, C.

The iron lid, S T, is, in the present view, at $1\frac{3}{4}''$ above G H; it is $\frac{5}{8}''$ thick. On it is a boss $\frac{3}{8}''$ thick, to which a flange runs from each corner, and on this boss is a box $\frac{3}{8}''$ high, in which the end of the screw works.

From this box, the screw, which is 1″ in diameter, is $7\frac{1}{8}''$ long.

At 1″ above this draw U V, the central horizontal, for the handle.

The boss in the middle of the handle is 2″ high and 3″ diameter. The length from end to end of the handle is $17\frac{1}{2}''$.

The screw is to be drawn in straight lines, as shown in previous examples. The nuts, etc., will be easily understood without further instructions.

ANIMAL COMMERCIAL PRODUCTS.—XVI.

PRODUCTS OF SUB-KINGDOM ANNULOSA (*continued*).

Blister Fly (*Cantharis vesicatoria*).—A small coleopterous insect about three-fourths of an inch long, of a nauseous odour and a brilliant golden-green colour. These insects secrete in their bodies a principle which has the power of vesicating or blistering the human skin when applied. For this purpose the beetle is reduced to powder, which, mixed with ointment or lard, is spread thinly upon a piece of leather, and then applied to the part intended to be blistered. The blister fly is found on a variety of shrubs in Spain, Italy, France, etc. It has been taken occasionally in England, but it is much more abundant in Spain; and although we now receive it principally from Astracan and Sicily, it still retains its usual commercial name of Spanish fly. In some years as many as twelve tons of these insects have been shipped from Sicily. Some idea of the immense number destroyed to form that amount may be obtained from the fact that fifty of them scarcely weigh a drachm.

Lac Insect (*Coccus lacca*).—The habits and economy of this insect are much the same as those of the cochineal. The lac insect attaches itself to the bark of trees abounding in milky juice—such as the *Ficus indica* or Indian fig, and the *Ficus religiosa* or Banyan fig—punctures the bark, and causes an exudation of the milky juice; this eventually surrounds the lac insect, her eggs, and larva, producing an irregular resinous-looking brown mass on the branch, which it encircles. The commercial varieties of lac are *stick lac*, which is the substance in its natural state investing the small twigs of the tree; *seed lac*, the same substance broken off in small pieces from the twigs; and *shell lac*, consisting of the substance melted and formed into thin cakes. Seed lac and shell lac are the resin left after the dye has been extracted from the stick lac. Lac dye and lac lake are two preparations of the colouring matter of stick lac, imported in small cubic cakes from the East Indies. The colouring matter of these dyes much resembles cochineal, for which it is largely substituted. Upwards of 1,000,000 lb. are annually imported from Bengal, and 3,000,000 lb. of shell lac; nearly one-half of it, however, is again exported to Italy, Germany, and other parts of the Continent.

Lac is mainly consumed in the manufacture of dye stuffs, sealing-wax, and of certain varnishes and lacquers. Red sealing-wax has its colour communicated by vermilion; white sealing-wax is made with bleached gum lac; black sealing-wax is a mixture of shell lac and ivory black; and blue sealing-wax is made by colouring the shell lac with smalt or verditer. To make golden sealing-wax, powdered yellow mica is mixed with the shell lac.

PRODUCTS OF THE SUB-KINGDOM RADIATA.

Radiata (Latin, *radius*, a ray) is the fourth primary division of the animal kingdom, and includes all those animals which have a radiated disposition of the organs of locomotion and internal viscera around a common centre, whence the term *radiated animals*. Their nervous system and instincts are reduced almost to a nullity; all are indolent and slow of movement, while many of them are rooted and fixed. They have been subdivided into the following classes:—

1. *Echinodermata* (Greek, *echinos*, a hedgehog, and *derma*, the skin), or spiny-skinned animals. Examples: asterias or sea-star, and the common echinus or sea-egg.

2. *Acalephæ*, or jelly-fishes, called also sea-nettles, because leaving, when touched, a disagreeable sensation, like the sting of a nettle. These have an extremely soft, gelatinous structure, and float and swim in the water by alternate contractions and dilatations of the body.

3. *Polypi*, or animals having a fleshy cylindrical hollow body, the mouth of which is surrounded by numerous arms or tentaculæ, and commonly fixed by one end. Examples: hydra or water polyp and the coral polyps.

Of the above classes of radiated animals, the last only is of commercial importance; it furnishes us with the

Red Coral (*Corallium rubrum*, L.).—This is a marine production, formed by numerous polyps in union with each other, called a polypidom. Recently taken, coral is covered with one continuous living membrane, in which are the polyp cells. These polyps produce the coral, a branched tree-like structure, beautifully red, and very hard, and for this reason much sought after for ornamental purposes. In places where good coral is obtained it forms an important article of commerce. It is abundant in various parts of the Mediterranean Sea. It occurs in the Red Sea, the Persian Gulf, and on the coasts of Spain, France, Corsica, Sardinia, and Sicily. Very fine coral is found between Tunis and Algiers, off the coast of Barbary, where the French and Italians carry on the coral fisheries. Other species of the genus have from time to time been dredged off Madeira and the Sandwich Isles.

Coral always grows perpendicularly on the surface of the rock to which it attaches itself, in whatever position the rock may be placed, and from eight to twelve inches in height. Coral requires from eight to ten years to arrive at its full growth. It is dredged up from depths varying from 10 to 1,100 fathoms. Its value depends on its size, solidity, and the depth and brilliancy of its colour. Some of the corals in the market are worth from eight to ten guineas an ounce, whilst other kinds will not fetch one shilling a pound.

PRODUCTS OF THE SUB-KINGDOM PROTOZOA.

Protozoa, or first animals (Greek, *protos*, first, and *zoon*, an animal). Examples: Infusoria, or animalculæ developed in vegetable infusions and sponges.

Sponge (*Spongia officinalis*, L.).—This organism is now acknowledged by naturalists as belonging to the animal world. A piece of sponge shows on its surface an indefinite number of minute holes, amongst which there are larger openings scattered. When alive and in the water, currents of water are seen to enter the smaller openings, which, after passing through the body of the sponge, are ejected out of the larger orifices. Nutritive matter is conveyed by these currents into the body of the sponge, and fæcal matter is at the same time removed. A coating of living gelatinous matter is spread all over the fibres of the sponge, in consistence like the white of an egg. This runs away freely from the sponge when the latter is taken out of the water. Nothing then remains visible but the sponge, which is, in fact, the horny skeleton or structure formed by the labours of the animals constituting the gelatinous coating.

Sponges occur in all seas, from the equator to the poles, but they attain their greatest size and perfection in the tropics. They grow on anything which will serve them as a point of attachment.

Several kinds of sponge come into the market, but the most valuable, and those also most in general use, are called Turkey and West India sponges. The former is considered to be the best. The tubes and orifices of the Turkey sponge are smaller than those of the West India variety; it is also more durable, and less easily torn. The Turkey sponge is obtained from the Mediterranean, where it grows on rocks and stones at the bottom of the sea in masses from the size of an egg to that of a man's head. Our supplies are received from Cyprus and Candia, from the shores of Anatolia, and from several islands of the Grecian Archipelago, especially from the small island of Symis or Syme, whose inhabitants are said to be the best divers. The coast of Syria furnishes the finest toilette sponges, valued at from 35s. to 40s. per pound; ordinary sponge costing only 10s. per pound. Inferior sponge, with a large-holed texture, called horse sponge, comes from the coasts of Barbary, Tunis, and Algiers. In 1886 there were imported into the United Kingdom 1,371,007 lbs. of sponges, valued at £229,817. The coarser sponges come principally from America. Very large ones are obtained from the Bahama banks and the coast of Florida.

The property which sponge possesses, of absorbing water into its tubes and retaining it until squeezed out, renders it valuable for all purposes involving washing and cleansing.

PRACTICAL PERSPECTIVE.—IV.

FIG. 20.—The subject of this lesson is a cross, made of square timber, or stone.

The picture-line, height of spectator centre, and points of distance having been fixed at pleasure,

From A set off A B, representing the distance of the perpendicular of the cross on the left of the spectator, and beyond this mark off C′, so that B C′ may equal the thickness of the material of which the cross is supposed to be made. Draw the perpendiculars C′ E and B D, and join them by the horizontal E D.

At the required height from the picture-line draw the horizontal line G I.

Make I I′ and G′ G equal to C′ B. At G and I erect perpendiculars, also equal to C′ B. Draw F F′ and H H′, and these will complete the front elevation of the cross.

Now from the angles B, D, G, H, I, and I′ draw lines to the centre of the picture. From B set off B J equal to C′ B.

From J draw a line to the point of distance, cutting B C in K.

At K erect a perpendicular, cutting I′ C in L, and meeting D C in M.

Through L draw a horizontal line, cutting I C in N, and G C in O.

At N erect a perpendicular, meeting H C in P, which will complete the perspective view of the cross when standing in the immediate foreground, on the left of the spectator, its elevation being parallel to the plane of the picture.

Fig. 21.—In this study the cross is represented as rotated, so that the elevation is at right angles to the plane of the picture. The attention of the student is called to the fact that whilst in the former view the foot of the cross was on the picture-line, it is not so in the present study. A moment's reflection will show that the upright must recede from the foreground in order

From J mark off J K, equal to J B, and from K draw a line to the centre of the picture.

Draw B′ K′ parallel to J K, which will be the bottom line of the upright of the cross.

At K′ draw a perpendicular, meeting a horizontal drawn from D in M.

On K erect a perpendicular, K S′, and a line drawn from S′ to the centre of the picture should pass through M.

Draw horizontal lines from H and I, cutting K S′ in P and N. Strengthen P N, and the square H I N P will be the end of the cross-arm.

From N draw a line to the centre of the picture, cutting K′ M in L. Draw I′ L, which will give the junction of the arm with the upright; a horizontal line from G will then complete the view.

Strengthen the lines required in the projection itself, in order that the object may stand clearly out.

Fig. 22.—The object of this study is to show the method of putting steps into perspective.

The four steps are contained within the square A B C D. Having drawn this square, and divided it into the required number of squares (that is, provided the steps are *squares*,

Fig. 20.

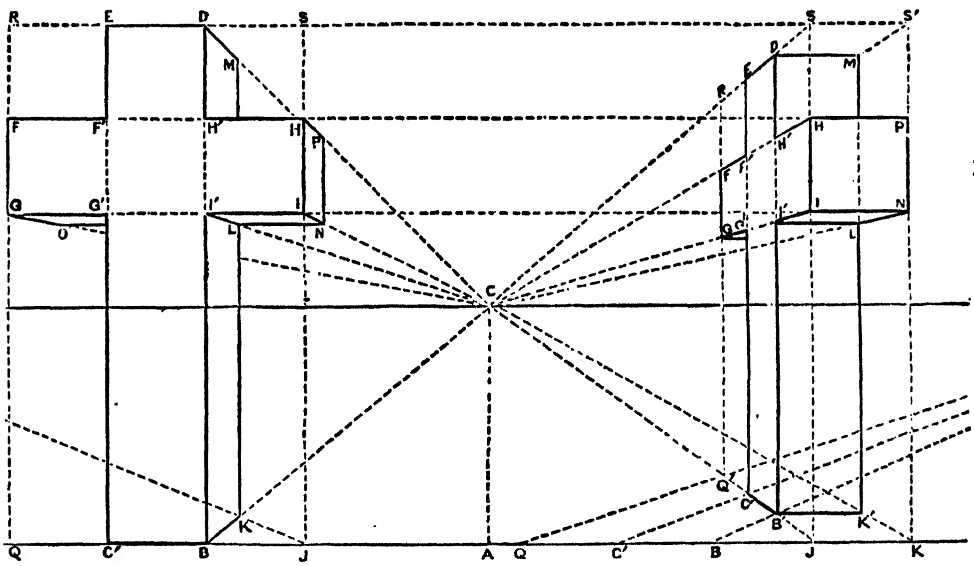


Fig. 21.

to allow of the projection of the arm, the end of which touches the picture-plane.

Now let us suppose the first cross to be moved along the picture-plane until the point J is at J of Fig. 21. If, then, on this point J we erect the perpendicular J S, and rotate the rectangle J S R Q′ on this, as a door on its hinges, we shall obtain the figure in which the cross will be contained.

Having erected the perpendicular J S, draw a line from each of these points to the centre of the picture. Mark off from J the length J Q (Fig. 20), and from Q draw a line to the point of distance, cutting J C in Q′.

Draw Q′ R, which will complete the perspective representation of the rectangle containing the cross, when its plane is at right angles to the plane of the picture.

On J S set off I and H, equal to the height and thickness of the arms.

On the picture-line set off from J the length of the arms J B and C′ Q, thus leaving between them the width of the upright of the cross. In the present study these are all equal, but of course this is not necessarily the case.

From B and C′ draw lines to the point of distance, cutting J Q′ in B′, C′; at these points erect the perpendiculars B′ D and C′ E.

From H and I draw lines to the centre of the picture, and draw F G, which will complete the perspective view of the elevation of the cross.

It now remains to give the appearance of solidity to this representation.

otherwise the containing figure must be an oblong formed of the required number of steps of the desired proportions), strengthen such of the lines as are required to form the angles of the steps—viz., B I, I F, F E, E G, G H, H I′, I′ J, J D.

From each of these points draw a line to the centre of the picture.

From B set off on the picture-line B K, equal to the real length of the front of the steps.

From K draw a line to the point of distance, cutting B C in K′.

At K′ draw the perpendicular K′ I″, and from I″ draw the horizontal I″ F′; continue the perpendiculars and horizontals, F′, E′, G′, H′, I′, J′, and D′, which will complete the figure.

Fig. 23.—The subject of this lesson is the same block of steps, turned so that their length is parallel to the picture-plane.

From A, the point immediately under the centre of the picture, set off A B, the distance of the object on the right of the spectator.

At B erect a perpendicular, B C′, equal to the height of the containing square or parallelogram.

From B and C′ draw lines to the centre of the picture.

From B set off B A′, equal to the base of the containing square or rectangle.

From A′ draw a line to the point of distance, cutting B C in A″.

At A″ draw the perpendicular A″ D; then B C′ D A″ is the perspective representation of the containing figure.

On B C′ set off the divisions corresponding with the number and height of the steps—viz., 1, 2, 3, and from these points

draw lines to the centre of the picture. On B A′ set off the divisions corresponding with the number and width of the treads of the steps—viz., 1, 2, 3.

From 1, 2, 3 draw lines to the point of distance, cutting B A″ in 1′ 2′ 3′.

At 1′ 2′ 3′ erect perpendiculars, and these cutting the lines drawn from 1 2 3 (in the line B C′) to the centre of the picture will give the angles of the steps E, F, G, H, I, J, and will thus

EXERCISE 11.

There is a stone cross, the perpendicular of which up to the arm is 7 feet; this perpendicular is at base 1 foot square. The arm, which is 1 foot square, rests on the perpendicular, and stands out 2 feet on each side; above this arm the perpendicular is continued so as to make the total height of the cross 10 feet. The scale is ¼ inch to the foot, the height of the spectator is 5 feet, the distance 12 feet.

(1.) Put this cross into perspective when standing in the foreground at 8 feet on the left of the spectator.

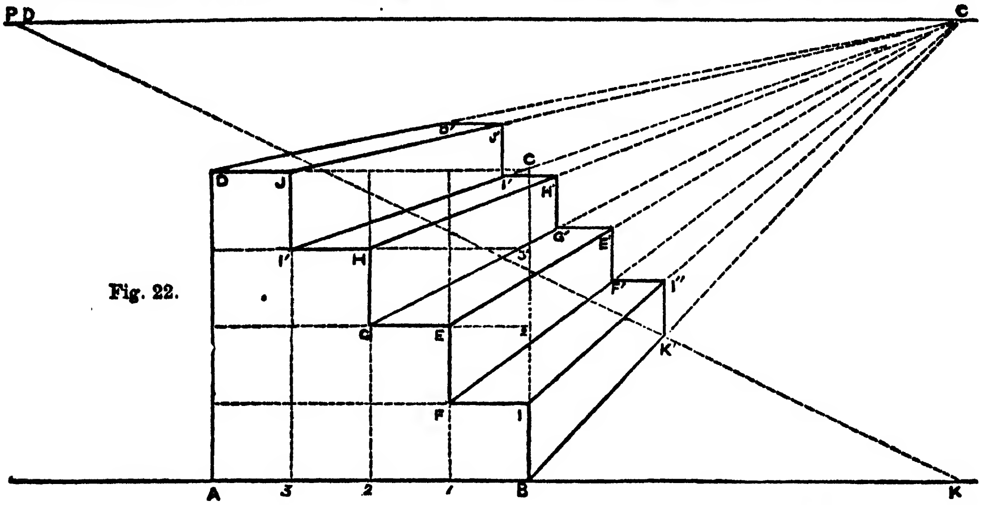


Fig. 22.

complete the perspective view of the end of the block of steps. From B set off B K, equal to the real length of the front of the steps.

Now from I (on the line B C′) draw a horizontal, and from K draw a perpendicular. These, intersecting in I′, will give the front of the first step.

From I′ draw a line to the centre of the picture, and from E draw a horizontal to intersect it in E′.

(2.) Put the same subject into perspective, at the same distance on left of spectator, but standing 10 feet back in the picture.

EXERCISE 12.

The scale, height of spectator, and distance the same as in the previous exercise.

(1.) Put the cross into perspective when standing at 9 feet on the right of the spectator, its face being at right angles to the picture-plane.

(2.) Put the same cross into perspective when standing at 6 feet

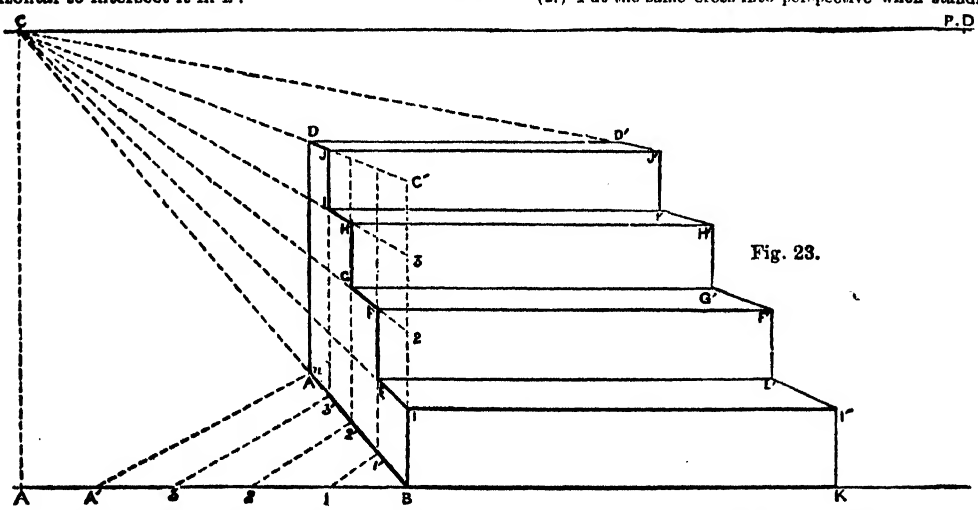


Fig. 23.

At E′ erect a perpendicular, and from F draw a horizontal to intersect it in F′.

From F′ draw a line to the centre of the picture, and intersect it by a horizontal drawn from G, thus obtaining the point G′.

From G′ draw a perpendicular, and from H draw a horizontal to intersect it in H′.

From H′ draw a line to the centre of the picture, and a horizontal from I to intersect it in I′.

At I′ erect a perpendicular, and intersect it in J′ by a horizontal drawn from J.

From J′ draw a line to the centre of the picture, and intersect it in D′ by a line from D, which will complete the study.

on the right of the spectator, and 8 feet within the picture, its face being at right angles to the picture-plane.

EXERCISE 13.

The scale is ½ inch to the foot, the height of the spectator is 6 feet, and his distance 15 feet.

There is a flight of 6 stone steps; the rise is 6 inches and the tread 9 inches, and the length of the steps 6 feet by scale.

(1.) Put this block of steps into perspective when placed at 7 feet on the left of the spectator, the end elevation being parallel to the picture-plane.

(2.) Put into perspective the same block of steps when standing so that their long edges are parallel with the picture-plane, the end elevation being at 5 feet on the right of the spectator.

CIVIL ENGINEERING.—V.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

CANALS (*continued*).

THE engineer having decided upon the most desirable course to be taken by the canal—the centre line having been staked out—next proceeds to lay out the *centres of cutting* for the various sections. These points will best be understood and explained by the help of diagrams. In excavating for the bed of a canal it is very seldom necessary to dig out soil equal to the capacity of the intended channel, because, in almost every case, the soil which is excavated can be utilised on the spot, by being deposited upon one or both sides of the excavation, and, by properly puddling and solidifying it, making it form the upper portions of the bed or the banks. Thus frequently nearly half the labour and expense is saved.

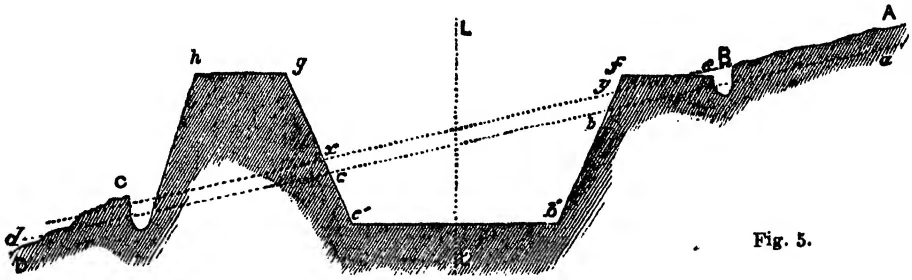


Fig. 5.

To accomplish this, however, it will be necessary to determine what shall be the depth and capacity of the excavation, so that, when the soil taken out is banked upon its margins, the completed channel shall have the capacity and dimensions it is intended the canal shall have. Now, it is with the view of determining this point that the "centre of cutting" is required.

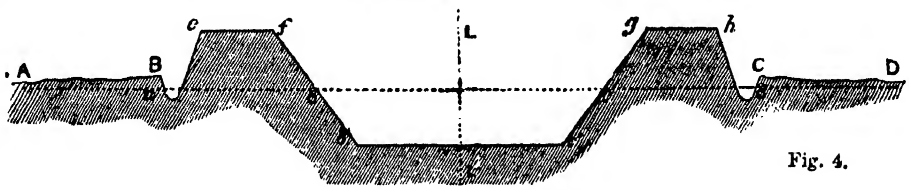


Fig. 4.

Our space prevents our entering fully into the rules requisite for determining the position of this point, which will vary greatly according to circumstances, and principally according to the direction, slope, or angle of the original surface of the ground, relative to a line standing vertically in the centre of the channel.

Let A B C D (Fig. 4) represent the surface of the ground, and let the first condition of the surface be that of a horizontal plain. This line will then be at right angles to L L′, the line standing vertically in the centre of the channel. In this case the dotted line *a b c d*, in which lies the centre of cutting, will occupy such a position as that the area of the quadrangle *b c c′ b′* shall be equal to the sum of the areas of the quadrangles *a e f b* + *c g h d*, in which *e f* and *g h* are the towing-paths on the sides of the channel *f g c′ b′*, the small grip ditch at *a* and *d* being formed to carry off the drainage from the banks.

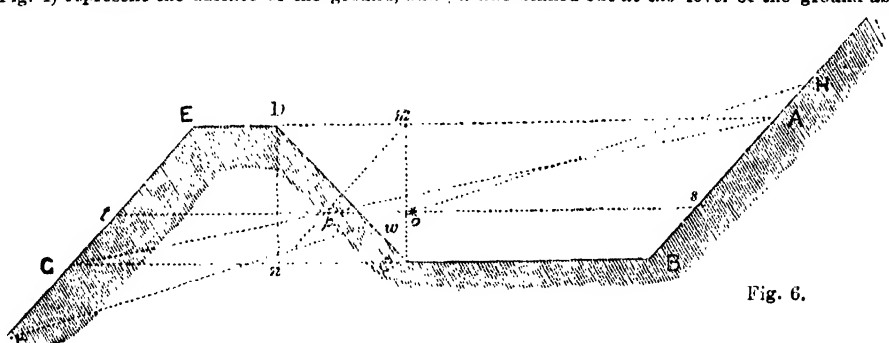


Fig. 6.

The enormous advantages which result from the adoption of this plan become apparent from an examination of the diagram. It will there be seen that only the lower and narrower portion of the channel has really to be excavated, the upper and wider part being built up, as it were, of the excavated soil.

The second condition we have to consider is, when the surface-line of the ground A B C D (Fig. 5) is not at right angles with the vertical line L L′. In this case it may not be necessary to disturb the ground at all upon the upper side of the slope, except to excavate for the towing-path *ef*, and the drain at B. The line *a b c d* through the centre of cutting will, in this instance, be determined upon by the consideration that the whole of the excavated soil can be utilised upon the lower side of the channel only; the capacity, therefore, of the figure *y b′ c′ x* must equal that of the figure *x g h* C, *y x* being in the line of the ground level, *e f* and *g h* being the towing-paths, and *f b′ c′ g* the channel of the canal.

It will be necessary to give one rule only for obtaining the centre of cutting. Take a case of *oblique cutting—i.e.*, where the canal has to be formed on the side of a hill, the inside and outside slopes being parallel, and one bank only required:—Let A B C D (Fig. 6) be the section of the intended canal, and C D E G F that of the bank, the slopes A B and E F being parallel. To find the centre of cutting, continue the lines B C, D E to G and A; draw the perpendiculars C *m*, D *n*, and the diagonals A G, *m n*, intersecting at *p*; through *p* draw the parallel *s p t*, and bisect it in *o*; then *o* will be the centre of cutting, and if any line, H O F, be drawn through this point, cutting the slopes A B, E G produced, H B C *w* will always be equal to *w* D E F; and the total breadth of the canal and bank (A D + *n* G) will be to the breadth of the bank added to the base of the slope (*n* G + *n* C), as the depth of the canal from its surface is to the depth below the centre of cutting. This point *o* will also be the centre of cut and cover, for a line staked out at the level of the ground above the point *o* will show the middle of the land required for the canal.

Cases may arise, however, in which the excavated earth cannot be utilised. The soil may be entirely unsuited for the formation of the banks, and must be removed. In such a case the channel will have to be altogether excavated below the ground-level. Sometimes, as, for instance, in passing through towns, retaining walls have to be built, so that less breadth of land shall be required. In conveying canals over roads, or across ravines, it may be necessary to construct aqueducts of masonry, or troughs of iron. A handsome bridge of five arches, built of hard sandstone, conveys the Lancaster and Kendal Canal over the river Lune at a height of 62 feet above the water. This aqueduct is 600 feet long.

The next point for our consideration is the *lock*. This ingenious arrangement is intended to overcome the difficulties

attendant upon conveying a canal over unlevel ground, so that the navigation shall be continuous. There are other contrivances besides the lock for attaining this object; but for ordinary purposes the lock is the most desirable. Before the invention of the lock, inclined planes were made use of for enabling the barges to pass from one level to another, and it was only in 1460 that locks were first employed upon canals. They were used in the Canal of Martezana, in Italy.

A lock consists of a portion of the canal fitted at each end with folding doors or gates, which when closed prevent the passage of the water through them, except when a valve or sluice, which is constructed in them, is opened. By means of these gates and valves the water in the intermediate portion can be brought to the same level with that either in the upper or lower section of the canal, and a barge enclosed between them will *descend* with the descent of the water from the upper to the lower section, or will *ascend* with the rise of the water from the lower to the upper section. The upper gates are called the *sluice*-gates, and the lower the *flood*-gates. The area of the lock should never be allowed to exceed what is actually required for the navigation, because every time a lock is emptied the enclosed mass of water descends to a lower level, and causes, by so much, a demand upon the source of supply at the higher levels. It is therefore desirable to reduce this mass of water as much as possible.

The difference of level upon the opposite ends of one lock should be kept, as nearly as possible, to 8 feet. If more than this, the strain caused by the water-pressure becomes excessive, and it is better to subdivide the height by a second lock.

The depth of a lock must be such that a barge navigating the lower section can float freely into it when the sluice-gates are closed and the flood-gates open, and the height of the flood-gates must be such that when closed, and the water admitted into the lock from the upper level, it shall not overflow them. The position of a lock is just at the termination of a level where the ground begins to fall. It is for every reason desirable to construct a lock of masonry, so that the wash of the water, caused by opening the sluices, shall not augment its capacity. Sometimes, when the traffic is heavy, as upon the Regent's Canal, in London, the locks are made double—that is, side by side, separated by a strong pier of masonry—and a flood-gate or valve is placed in this pier, by which communication can be made between the two locks. By this arrangement a saving of water is frequently effected, as, instead of allowing an entire lockful of water to pass into the lower section, half of it can be passed into the adjoining lock, should that happen to be empty at the time. Great care is needed in constructing the retaining walls and piers of locks. As a rule, the thickness of a wall intended to support the lateral pressure of water should not be less than half the height of the water which presses against it. The surface of the masonry should be set in cement, and the bonding should be arranged so as best to withstand the thrust of the closed gates.

The gates of locks are usually constructed of timber, although in some instances they are of iron. If of timber, they consist of two strong upright posts, the inner being called the *quoin*, or *hanging* post, and the outer the *mitre*, or *shutting* post. These are framed together with several horizontal rails or cross-bars, and the whole consolidated by braces *closely* laid, and placed either vertically or diagonally, the dip of the diagonal being *downwards* from the hanging post. By this means the stress is transferred to that post. The valves or sluices are small doors sliding vertically over orifices left in the framework of the gate, and usually raised and lowered by a rack and pinion worked from above. The hanging of the gates demands great care. They must be made to fit so accurately both at the ... and middle, as that very little, if any, water can percolate through when they are closed. Their lower centre moves in an iron plate leaded into the stone-work, while the upper is supported by a strap keyed or bolted to attachments let into the upper courses of masonry. The strap, by the action of the keys or bolts, can be altered in its position, to allow for wear in the centre, and for other purposes, such as the ready unhinging of the gate for repairs. In Fig. 7 is shown a plan of the ordinary arrangement of hanging; C being the centre of the gate G, S the strap passing round the centre, and P the iron plate let into the masonry.

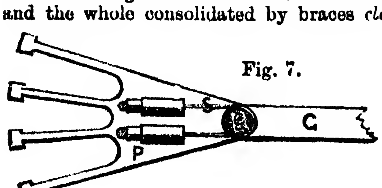


Fig. 7.

As it would be impracticable to allow the gates to rest upon the ground, owing to the friction which would result,

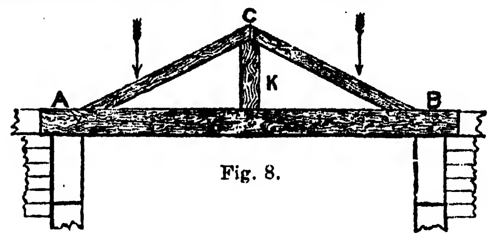


Fig. 8.

and as, nevertheless, any space which existed under the gates when closed would be the cause of considerable leakage, when the level of the water is higher on the resisting side, their bases are made to close against a timber sill, called a *mitre sill*, the angle of which must agree accurately with that at which the gates are intended to remain when shut. This sill is partly embedded into the masonry on the bottom of the lock, and is framed as shown in Fig. 8. The arrows indicate the direction of thrust.

The piece A B runs transversely across the lock, the ends being worked into the side walls under the hollow quoins. The angle A C B, which, as we have stated, must correspond with the angle at which the gates stand when shut, varies according to the views held by engineers. It must certainly vary with the size of the gates—that is, with the pressure of the water. The larger the gates the more acute the angle should be. The reason for this is obvious: since if the gates are small, the pressure of water, being less, would scarcely ensure the efficient closing of the gates, if the angle be too acute; whereas if the gates are large, the great pressure of water would act injuriously against the bearings of the gates, if the gates closed at too obtuse an angle. The nearest approach to a rule we can lay down is, that when the head of water is from 5 feet to 9 feet, the length of the king-post K (Fig. 8) shall be one-fifth of the length of the opening of the lock; if the head be less than 5 feet, the king-post may be one-sixth of the opening.

Owing to the fact that the flood-gates are sometimes partly submerged, and sometimes entirely out of the water, their weight will vary. Long levers are therefore fixed to them, to facilitate opening and shutting them, at the same time being made very heavy to balance them. If the gates are very large and very heavy, the balance levers are dispensed with, and the gates are furnished with small iron wheels, upon which they rest, and which run on iron rails curved to the arc they describe. The gates are in this case opened and closed by means of chains attached to them.

SEATS OF INDUSTRY.—V.

GLASGOW.—I.

BY WILLIAM WATT WEBSTER.

Glasgow is by far the largest town in Scotland, and in point of wealth and population ranks second among the cities of the United Kingdom. It is at once one of the most ancient and one of the most flourishing centres of commercial and manufacturing enterprise in Britain. All the principal phases through which trade and manufactures have passed since the dawn of the modern industrial era are illustrated in the story of this city. Entering early on a commercial and manufacturing career, Glasgow has steadily maintained the foremost place among the industrial towns of Scotland; and every great discovery or improvement in the methods of production and transit has, quickly after its introduction, been made to contribute to its prosperity.

The spot now occupied by Glasgow was the site of a Roman station, and the remains of a Roman camp are still to be seen at a place called "Camphill," two miles to the south of the city. Glasgow formed part of the province of Valentia, which was bounded on the north by the wall of Antoninus, that ex-

tended from the Frith of Forth to the Frith of Clyde, and it is believed that it continued in the possession of the Romans till about the year 426, or shortly before the time when they finally abandoned the island. There is a tradition that the site on which the cathedral of Glasgow stands was consecrated as a burying-ground by St. Ninian of Galloway, as early as the beginning of the fifth century; and historians are agreed that a religious house or see was established there by St. Mungo, or, as he was also styled, St. Kentigern, about the year 560. The city, undoubtedly, had its origin in a religious establishment, and St. Mungo is its reputed founder. Several fathers of the Roman Catholic Church have recounted the fabulous achievements of this holy ecclesiastic, and those portions of the legendary story of his life which explain the arms and motto of the city with which his name has been associated for so many centuries may fitly find a place in this paper. The arms of Glasgow consist of a tree, with a bird perched in its boughs; on one side is a salmon with a ring in its mouth, and on the other a bell. The tree is said to commemorate a miracle which St. Kentigern performed at Culross, when he broke a frozen bough from a hazel, and kindled it into flame by simply making the sign of the cross over it. Regarding the ring and the fish, an equally extraordinary story is told in the monkish legends. The queen of Cadzow having lost a ring presented to her by her lord, who threatened to put her to death if it could not be found, went to St. Kentigern in great distress, and besought him to put forth his supernatural power to recover the missing jewel. After he had concluded his devotions, the saint went forth to walk along the banks of the river Clyde, as his custom was, and seeing the fishermen plying their vocation, he asked them to bring him the first fish that was caught. It is hardly necessary to add that the ring was found in the mouth of the fish, and that the lady was saved from the fate which threatened her. The bell is the effigy of a famous bell that St. Kentigern brought from Rome, which was preserved in Glasgow till the Reformation, if not to a more recent period. There is no miraculous story associated with the bell. It is otherwise, however, with the motto:—"Let Glasgow flourish by the preaching of the word." Having incurred the hostility of the heathen chief of Cumbria, St. Kentigern was compelled to fly from the newly-organised settlement at Glasgow, and seek refuge in Wales, where he abode for some years, and founded the bishopric still called after his disciple, St. Asaph. When his enemy died, the holy man returned to the scene of his former labours, and was welcomed back by a great crowd. Beginning to preach the Gospel to the thronging multitude, St. Kentigern soon found that it was impossible, owing to the flatness of the ground, to make himself heard, except by those in his immediate neighbourhood. This acoustic defect, however, was soon remedied; for, lo! on a sudden, the plain on which he stood was transformed into a hillock, from whence he was both seen and heard. According to the legends, St. Kentigern received the name of Mungo from his spiritual father St. Servan, the Culdee of the Inch of Lochleven, whose favourite disciple he was; and the word *Mungo* or *Mungah* signifies in the Norwegian language "dear friend." For five hundred years after the death of St. Mungo, which occurred in 601, the history of Glasgow is almost a blank. The people who inhabited the valley of the Clyde are believed to have acquired a certain degree of civilisation from being brought into close contact with the Romans, and the "Kingdom of Strathclyde," which was founded after the departure of the Romans, was intact at the time when Bede, the historian, died in 735. One of the princes of the Strathclyde dynasty conferred a grant of lands on the religious house which St. Mungo established; but the fraternity were robbed and maltreated, alternately by Picts, Scots, Saxons, and Danes. In 1115, David, Prince of Cumberland, repaired the devastations of St. Mungo's settlement; and in 1129, five years subsequent to his accession to the throne of Scotland, this pious and munificent sovereign appointed his preceptor, John, commonly called Achaius, to be bishop of the see. A few years later the pile was rebuilt, and on its consecration David I., in addition to his previous gifts, conferred on the community of St. Mungo the valuable lands of Partick, which are now in the possession of the University of Glasgow. The liberality which this sovereign displayed towards the Church gained him the title of Saint, and caused one of his successors on the throne, James V., to grumble that he had been "ane sair sanct for the croon." There are no means of determining whether Glasgow had at this period attained the dimensions of a town, but the nucleus round which the city has gathered and grown was now formed. The claim of King David I. to be considered the re-founder of the city, is at least as good as that by which St. Mungo holds the title of founder. In 1181 the building erected by David I. was replaced by the present pile; and in 1190, King William the Lion raised Glasgow to the dignity of a royal burgh, with the privilege of an annual fair, which is still held. For the next century and a half, however, Glasgow remained a small town of some fifteen hundred inhabitants. The first bridge across the Clyde was built by Bishop Rae, about the year 1345; and in 1451 Bishop Turnbull, on the authority of a bull obtained from Pope Nicholas V., established the University. But although the latter exercised almost as important an influence on the early fortunes of the city as the erection of the cathedral, yet as late as 1550 Glasgow was only the eleventh among the towns of Scotland.

Commercial enterprise began to manifest itself in Glasgow at a comparatively early period. John M'Ure, *alias* Campbell, "Clerk to the Registration of Seisins and other Evidents for the District of Glasgow," published a history of the city in 1736, when he was in his seventy-ninth year, from which we learn that "the first promoter and propagator" of the trade of the place was William Elphinstone, a cadet of the noble family of that name, and father of Bishop Elphinstone, the founder of King's College and University at Aberdeen. This trading worthy acquired wealth and fame about the year 1420, by curing salmon and herrings, and exporting them to France and other Continental countries, bringing back brandy, wine, and salt in exchange. M'Ure mentions as the "second promoter and propagator" of trade, Archibald Lyon, a younger son of Lord Glamis, who was brought to Glasgow near the close of the fifteenth century by Archbishop Dunbar, and who became a great merchant, and "undertook great adventures and voyages in trading to Poland, France, and Holland." The success of this high-born merchant is attested by the extent of the possessions he acquired in and around Glasgow. In the inventory of his wealth the following items occur:—"A great lodging for himself and family upon the south side of the Gallowgate Street; four closes of houses and forty-four shops, high and low, on the south side of the Gallowgate; and a part of the left side of the Saltmarket." But the foreign trade of Glasgow at this time must have been trifling, although about the year 1600 the prosperity of the foreign merchants excited the jealousy of the tradesmen, who wished to share the advantages enjoyed by the former; and the disputes between them led to the establishment of a guildry in 1605, for regulating and maintaining the limits of trade and commerce, having at its head a dean, who was to be "a merchant, a merchant sailor, and a merchant venturer." The effect of the regulations instituted by this guildry was, that none but guild brethren were in future permitted to trade or traffic in Glasgow. An interesting account of Glasgow half a century later is to be found in a report on the revenue from the excise and customs of Scotland, dated 1651. "With the exception of the coliginers," says Commissioner Tucker, "all the inhabitants are traders: some to Ireland, with small smiddy coals, in open boats from four to ten tons, from whence they bring hoops, rungs, barrel-staves, meal, oats, and butter; some to France, with plaiding, coals, and herrings, from whence the return is salt, pepper, raisins, and prunes; some to Norway for timber. There have likewise been some who have ventured as far as Barbadoes. . . . The mercantile genius of the people is strong, if they were not checked and kept under by the shallowness of the river, every day more and more increasing and filling up, so that no vessel of any burden can come up nearer the town than fourteen miles, where they must unload and send up their timber on rafts, and all other commodities by three or four tons of goods at a time, in small cobbles or boats, of three, four, or five, and none above six tons a boat. . . There are twelve vessels belonging to the port, none of which come up to the town—total 957 tons." The most notable among the merchants of Glasgow from 1651 to 1707 were Walter Gibson and John Anderson. The former had dealings with France, Spain, Norway, and Virginia, and was the first merchant who brought iron to Glasgow, while the latter is celebrated as the first merchant who imported wine direct into the city.

PRACTICAL PERSPECTIVE.—V.

FIG. 24.—The subject of this lesson is a cross, of a similar character to that shown in Figs. 20, 21; but in the present study the object is lying on the ground with the ends of its cross-arm parallel to the picture-plane.

It will be remembered that Fig. 20 was shown to be contained in a rectangle, and this plan is again adopted in the present lesson.

From A, the point immediately under the centre of the and G D will be the real length of the arms, and F G their width. From F and G draw lines to the centre of the picture, cutting D′ E in H, I. F H I G is the plan of the arm.

But the timbers of which the cross is made are of equal thickness, and therefore F G is not only the width of the arm but of the upright stem of the cross; and further, the arms project horizontally from the stem, precisely as much as the stem projects above them, and the space cut out of the corner of the containing rectangle is therefore a square, the side of which is B F. Therefore, from F and G draw lines to the point

Fig. 24.

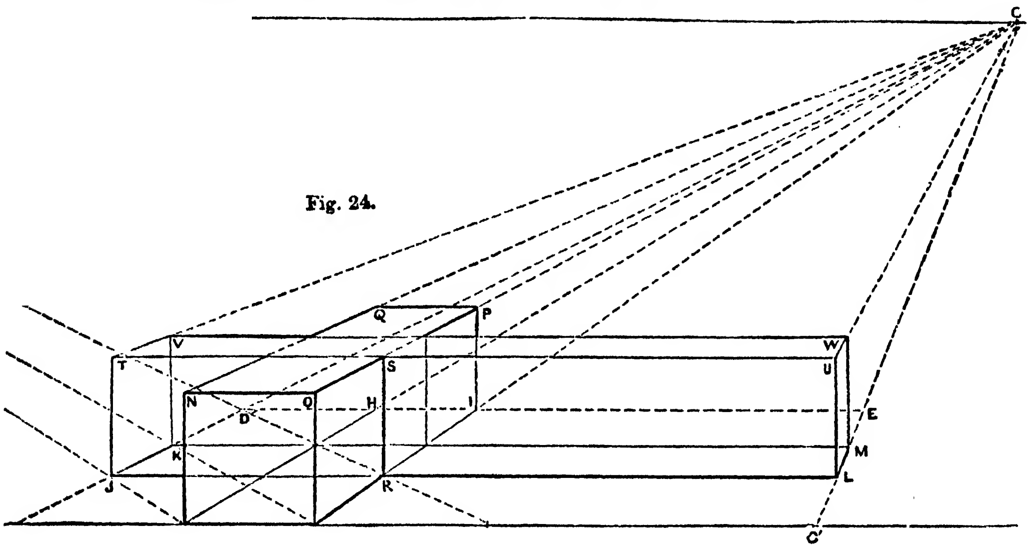
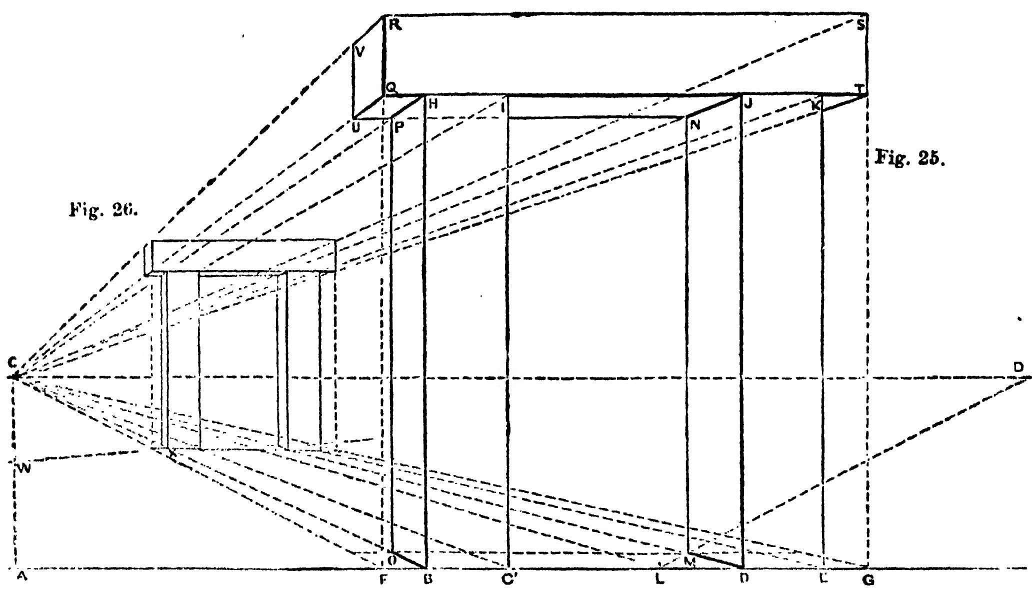


Fig. 25.

Fig. 26.



picture, mark off A B equal to the distance of the top of the cross on the left of the spectator; and from B set off towards A the distance B C′, representing the entire height of the cross.

From B and C′ draw lines to the centre of the picture.

From B set off B D, representing the width of the containing rectangle. Draw a line from D to the point of distance (the point of distance is not shown in this figure), which will cut the line drawn from B to the centre of the picture in D′.

At D′ draw a horizontal line, cutting C′ C in E, which will complete the perspective representation of the rectangle when lying on the ground.

Now between B and D set off the lengths B F, F G; then B F of distance, cutting the line drawn from B to the centre of the picture in J and K. Draw J L and K M, and these will complete the plan of the cross.

Now on F G construct a square, F G N O, which will be the elevation of the end of the arm.

From N and O draw lines to the centre of the picture.

At I draw a perpendicular, cutting O C in P, and at P draw the horizontal P Q, which will complete the solid rendering of the arm.

The line drawn from G to the centre of the picture cuts J L in R; at R erect a perpendicular, cutting O C in S. At J and L erect perpendiculars. Through S draw a horizontal, meeting

the perpendiculars J and L in T and U. At K and M erect perpendiculars. From T and U draw lines to the centre of the picture, cutting the perpendiculars K and M in V and W. Join V W by a horizontal, and this will complete the figure. Such lines as would be visible in the object are then to be strengthened.

Fig. 25.—The subject of this lesson is a simple doorway, consisting of two uprights, and a horizontal resting across them.

Having drawn the picture and horizontal line, and having fixed the centre of the picture and the point of distance,* mark off the distances A B, B C', C' D, and D E. These will give the positions of the uprights.

From B set off B F, and from E set off E G.

These spaces represent the length which the horizontal projects beyond the uprights. These would not be absolutely necessary if the one figure in the foreground only were to be drawn, but as a distant figure is to be added, it is advisable that they should be marked at the present stage.

Draw the perpendiculars B, C', D, E; join H I and J K, and from the upper and lower extremities of the perpendiculars draw lines to the centre of the picture.

From D set off D L equal to the width of the receding side of the upright, and from L draw a line to the point of distance, cutting the line D in M. At M draw a perpendicular, meeting in N, which will complete the view of one of the uprights. Draw a horizontal line through M, cutting the line drawn from B to the centre of the picture in O; also a horizontal line from N, cutting H in P. Then the perpendicular O P will complete the perspective projection of the second upright.

Produce the horizontal H K, and terminate it by perpendiculars from F and G, which will give the ends Q R, S T of the horizontal. From Q and R draw lines to the centre of the picture. Produce N P to meet Q in U, and from U draw the perpendicular U V. Q R V U will be the view of the end of the horizontal, and the projection will then be finished.

Fig. 26 represents the same object at a distance back in the picture. Draw lines from F and G to the centre of the picture, and having set off from B on the picture-line (at a point not shown in the figure) the distance which the figure is supposed to be from the picture-plane, draw a line from such point to the point of distance. (The position of this line shown in the figure is lettered W.)

The line W, intersecting B in X, will give the required position. Through X draw a horizontal, and this, intersecting all the lines drawn from the points in the foreground, will give the places of the perpendiculars in the distance, and the rest of the construction will be readily understood from the diagram.

* The student is advised to fix these at different distances from those in the figure. This will prevent his absolutely *copying* the diagrams.

Fig. 27.—In this figure the two objects are placed in a line, so that their faces are at right angles to the picture-plane.

Having fixed F as the distance of the objects on the left of the spectator, set off from it F L, equal to the breadth of the side of the object. This length is similar to L D in Fig. 25, which, seen perspectively, becomes D M.

From F and L draw lines to the centre of the picture; and it is in this track that the object travels as it recedes into the distance. From F mark off F B, C', D, E, G, as in the previous figure, and from each of these points, excepting F, draw lines to the point of distance, intersecting F C in B', c, D' E, and e. At F erect a perpendicular, and mark on it the heights Q and R. From Q and R draw lines to the centre of the picture.

Now from B', c, D', and E erect perpendiculars to meet Q in H, I, J, and L', and another from *e* will give S T.

At Q R draw horizontals, and at L erect a perpendicular. This will give the square Q R V U, representing the end of the horizontal; and from U draw a line to the centre of the picture.

From B' draw a horizontal, cutting L C in O, and at H draw a horizontal, cutting U C in P. Join O P by a perpendicular.

At D' draw a horizontal, cutting L C in W. At J draw a horizontal, cutting U C in N. Join W N by a perpendicular, and this will complete the view of the object.

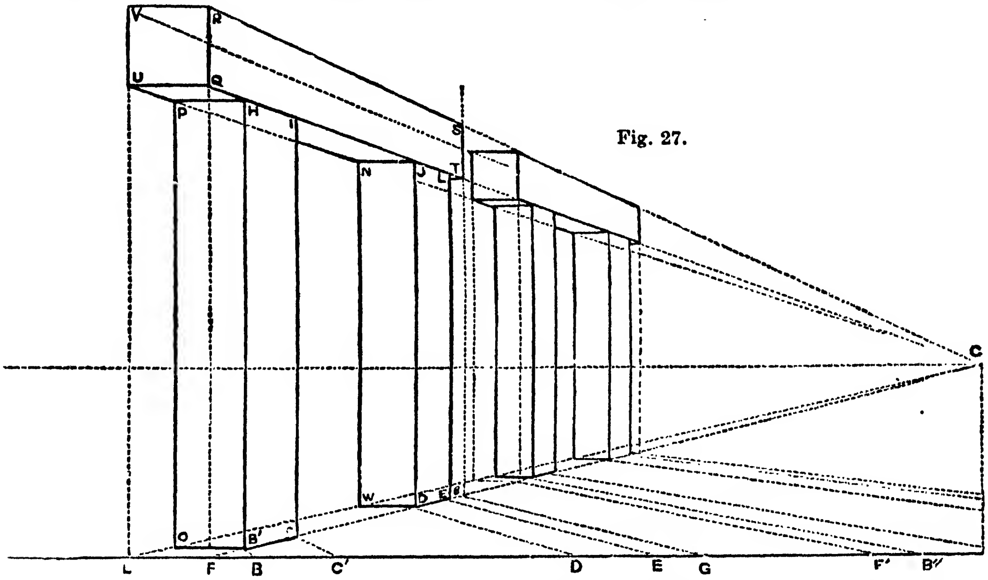


Fig. 27.

In commencing the second figure, set off from G the length G F', equal to the distance of the second object beyond the first. From F' set off B'', and all the other points as in the first figure.

From these points draw lines to the point of distance, intersecting the line drawn from F to the centre of the picture, as in Fig. 25, and from these raise perpendiculars. Then the lines drawn from Q, R, U, V to the centre of the picture will give the necessary points and lines for the horizontal, and so complete the figure.

WEAPONS OF WAR.—VII.

BY AN OFFICER OF THE ROYAL ARTILLERY.

GREAT GUNS AND THEIR PROJECTILES.

We now enter upon another stage of our subject. We have dealt hitherto with hand-weapons—weapons to be wielded by individual combatants, and comprised within the term "small-arms." We have traced, however imperfectly, the gradual development of weapons of this sort, through the stages of swords, spears, and pikes, of arrows, javelins, and missile weapons, up to the Needle-gun, the Chassepot, the Snider, and the Martini-Henry.

We must now turn to great guns, and consider the principal types of cannon in use in this and foreign countries.

The same principles which have governed the successive developments of small arms have applied to cannon, with some

modifications or additions. The power of being able to reach your enemy at a continually increasing distance, of being able to strike him with greater and greater certainty, of being able to do him more and more harm, and of accomplishing all this with the minimum of inconvenience and difficulty to oneself—this is the problem which for several centuries the artillerist has set himself to solve; and these conditions may be said to apply to all classes of ordnance, heavy and light. But the conditions imposed in the two cases are very different. In the case of the light gun, the object generally is to destroy men; in the case of the heavy gun, although the ultimate object is to carry destruction and dismay among the *personnel* of your enemy, that object can generally only be attained through the destruction of his *matériel*. Again, while there is practically hardly any limit to the size of the heavy gun, except the endurance of the weapon itself, the field-gun has to be of a weight no greater than will permit of its easy and rapid transport on a campaign, and from one part of a field to another. Lieut. Hime, R.A., in an interesting paper on Field Artillery, in the "Proceedings of the Royal Artillery Institution," observes that "motion is the essential difference between the two great branches of the artillery service, being as necessarily included in the conception of field artillery, as it is necessarily excluded from the notion of garrison artillery. The latter is the artillery of rest, the former is the artillery of motion; and an immovable field artillery is a contradiction in terms." Marshal Marmont used to say, "Le premier mérite de l'artillerie, après la bravourie des canoniers et la justesse du tir, c'est la mobilité." It would seem that this proposition might be fitly reversed—for no amount of gallantry, no amount of accuracy, would compensate for an absence of mobility. Gustavus Adolphus, at any rate, acted upon this principle, for, as Lieut. Hime tells us, he resolved at the commencement of the Thirty Years' War to increase the mobility of his field artillery "at all hazards," and he actually took the extraordinary step of introducing *leather* guns of great mobility, but of inferior accuracy as compared with the iron guns then in vogue. These leather guns did good service before they dropped into disuse.

Therefore, it is important to insist upon this fundamental distinction between field and garrison (or naval) artillery—the necessary mobility of the former.

But it would not do to divide artillery into two great groups, separated by a hard and fast line. On the contrary—while in the one direction field artillery shades off into mountain artillery, and garrison artillery developes into the monster turret guns, which are moved on huge turn-tables within the cupola or turret—the two classes of field and garrison meet on common ground, and almost imperceptibly shade off one into the other in guns of position and siege guns.

If we were required to classify artillery at all, we should adopt some such distribution as the following:—

1. Mountain guns.
3. Field guns { (a) Horse artillery. (b) Field artillery.
3. Guns of position.
4. Siege guns.
5. Garrison and broadside guns.
6. Turret guns.

Most of these classes admit of further subdivision—for there are mortars, howitzers, carronades, shell-guns, and guns proper; there are also smooth-bore and rifled guns; to these must be added the machine guns which have been invented of late years, such as the Nordenfeldt (4 barrels), with 1-inch bore; the Gatling (10 barrels), with ·45 and ·65-inch bore; the Gardner (5 barrels), with ·45-inch bore. It is evident, therefore, that an exhaustive treatment of every detail of this large subject is impossible within the limits of the present series of papers.

Until comparatively a few years ago nearly all artillery consisted of smooth-bores. Rifled guns of great variety and ingenuity of design had been prepared by sanguine inventors, and many of them had been experimented with. But the guns of the English service, like those of other nations, remained smooth-bores. It may be supposed that it is unnecessary to speak of smooth-bores now—that their day has gone by so completely as to invest them with no other than an antiquarian interest. This is not the case; it must take many years before smooth-bores disappear from our service; for some purposes—as for the flank defence of ditches, where range and accuracy are of no importance, while a high velocity of projectile is of very great importance—smooth-bores will probably always be retained. Again, at this moment there does not exist a single rifled mortar in the British service; while the Americans scarcely use any other than smooth-bore guns, even for their first-class armaments. So that, although the day of rifled guns dawned several years ago, that of smooth-bores has not yet set.

A smooth-bore gun is merely a hollow tube of iron, or steel, or bronze, or other suitable material, intended to project a spherical projectile. The expression "smooth-bore" has reference, of course, to the unrifled condition of the bore.

The largest smooth-bore gun in the British service prior to 1858 was the 68-pounder, so called because the solid spherical shot which was discharged from it weighed 68 pounds. The gun itself weighed 95 cwt.,* and it fired a charge of 16 pounds of powder. It is interesting to compare this, the biggest English gun of 1858,† with the biggest English gun of 1883.‡ The latter is a 1,900-pounder, its weight is 100 tons, or 2,000 cwt., or more than 20 times that of the 68-pounder. The charge of the 100-ton gun is 337 lb., or 450 lb. of powder. Before we come to speak more particularly of the heavy guns, we have a great deal of ground to cover. But it seemed interesting to show by this contrast the strides which have been made in twelve years. All the heavy English smooth-bore guns were made of cast-iron—about as bad a material as could well be employed for ordnance, because of its comparatively low resisting power and its liability to yield suddenly, and without warning when it did yield, and thus to cause what artillerymen most dread—an explosive burst. However, for firing the comparatively low charges then in vogue, the cast-iron was fairly suitable. It is true that the annals of our artillery are darkened by the record of many disasters due to the bursting of these guns; but it is probable that, had it not been for the introduction of rifled artillery, and the new conditions imposed upon the gunmaker, cast-iron would have continued to be employed for several years to come.

Where great lightness was required—as for field-guns—bronze or "gun-metal" was employed. Bronze is an alloy of copper and tin in the proportion of about 11 to 1. The advantages of this material are its lightness, its non-liability to explosive rupture, its value as old metal when the gun is worn out, and the facilities of production. On the other hand, the softness of bronze has always constituted an objection to its use for artillery; this softness was apt to cause the guns to become bulged and unserviceable with long-continued firing, and "drooping at the muzzle" was a complaint to which bronze guns were considered to have been especially liable.

The smooth-bore field-guns of the British service were generally 9-pounder guns and 24-pounder howitzers for field batteries, and 6-pounder guns and 12-pounder howitzers for horse artillery. The howitzers differed from the guns in throwing heavier projectiles with greatly reduced charges. While the relation of the charge to the projectiles in the guns was about as 1 to 3½ or 4, in the howitzers the relation was about as 1 to 9 or 10. This reduction of charge enabled the howitzers, although firing far heavier projectiles, to be made thinner and shorter than other guns, which they thus did not exceed in weight—the 9-pounder gun and the 24-pounder howitzer weighing each about 13 cwt., the 6-pounder gun and 12-pounder howitzer weighing each about 6 cwt. The mode of carrying these pieces, as well as that of carrying and mounting guns generally, will be treated in a separate paper.

Between the field-guns and the 68-pounder before mentioned, there were a number of guns intended for a variety of purposes. The designation of these guns was as follows:—56-pounder, 42-pounder, 32-pounder, 24-pounder, 18-pounder, and 12-pounder. The 56-pounder and 42-pounder are fast becoming obsolete, but the other guns still exist in the service in considerable numbers. The whole of these guns were made of a weight and strength which permitted of the use of solid shot or shell, with relatively heavy charges of powder. There were, however, guns intended specially for projecting shell with low charges; these were the 10-inch and 8-inch shell-guns and howitzers.§ There were also

* There were some of 112 cwt.

† A few 150-pounder and 100-poun quently introduced.

‡ The 80-ton gun is the largest in common use.

§ The number of inches whence these guns have their designation refers to the diameter of the bore.

pieces designed for projecting either shell or shot with very low charges; these were called carronades. The charges for shell-guns and howitzers varied from about $\frac{1}{5}$th to $\frac{1}{12}$th the weight of the heaviest projectile; the charges for all carronades being fixed at about $\frac{1}{12}$th the weight of the shot.

Originally shells were not projected from guns and howitzers at all; they were thrown from mortars. A mortar is a short piece for throwing shells at an angle of 45° into an enemy's position; and for the bombardment of a town, or any large area, this "vertical fire," as it is called, is terribly effective. Indeed, it would be terribly effective against all positions, if sufficient accuracy could be obtained to insure hitting the object aimed at. But the comparative inaccuracy of vertical fire—the shell describing a roundabout path to arrive at its object, and being therefore for a longer time under disturbing influences than the shell from a gun—has hitherto constituted a formidable objection to its extended use. It will be easily understood that the effect of a shell falling on to the deck of a ship would be tremendous; but a ship, especially a ship in motion, presents such a small and difficult object for attack, as to entail an immense waste of ammunition in trying to hit it. The same objection does not apply to the employment of mortars against large entrenched positions, towns, etc. Attempts have been made to introduce rifled mortars, by which the irregularities of vertical fire may be, if not removed, at least diminished, while in range and general power such pieces would be vastly more effective than smooth-bore mortars. An interesting development of mortar-fire was suggested by Mr. Mallet, C.E., in 1858. Mr. Mallet proposed to throw enormous shells, 36 inches in diameter, weighing 2,481 lb., and containing each a bursting charge of 480 lb. (equal to nearly five barrels) of powder. Thus, the total weight of each shell filled was about 1¼ ton. Mr. Mallet also proposed a mortar of suitable proportions to project these monster shells. The proposition attracted a good deal of attention, and by Lord Palmerston's order two of the mortars and a number of the shells were supplied by Mr. Mallet for experiment. Both mortars and shells may be seen by visitors to Woolwich Arsenal, where they form objects of curiosity and interest. Mortars are designated by their calibres in inches. There are five sizes in the British service—viz., 13-inch, 10-inch, 8-inch, 5½-inch, and 4⅖-inch.

We see, then, that there existed smooth-bore ordnance suitable for throwing projectiles of all sorts, and of delivering a "horizontal" or a "vertical" fire; that these pieces were made of cast-iron, except those intended for field-guns, which, on account mainly of their greater lightness, were made of bronze. But a gun, after all, is only a means to the end. It is an instrument merely for throwing projectiles, with more or less of range and accuracy, more or less of destructive effect. We will therefore pass to the projectiles which were used with these pieces, before going on to state in what manner the range and accuracy of the smooth-bore guns has been improved upon, and how artillery has attained to the pitch of destructive power which it has now reached. We will therefore proceed to treat of the different classes of projectiles which are fired from smooth bore guns.

With the exception of such projectiles as were intended to break up at the muzzle and produce an immediate scattering effect, or projectiles which, like the ground light ball, were not required to have any special accuracy, the projectiles thrown from smooth-bore guns were all spherical, that form being the one which naturally, in the absence of rifling, could be thrown with more certainty and accuracy, and to a greater distance than any other. The two main classes of projectiles are shot and shell. There is a third class of incendiary and miscellaneous projectiles which must not pass unnoticed. The varieties of each class are much more numerous than persons generally suppose. Thus, the word "shot" generally conveys but one impression to the mind of the non-professional. It almost inevitably suggests the solid "round shot" of iron. But, in addition to round shot, there are solid steel shot, and solid chilled iron shot, hollow shot, case-shot, and grape-shot. The solid shot is the simplest and most primitive form of projectile, the object with which it is employed being, of course, to kill or disable an enemy, or to batter down or penetrate his defences. When defences were of brick and stone, or wood, or when troops fought in the open, it sufficed to make the shot of cast-iron; but when armour-plated defences came into vogue, it was necessary to use some other material. Accordingly, steel shot were introduced for use with the larger smooth-bore guns, with which some of our ships were still armed. The great cost of steel, however, and the success which had attended the employment of the famous Palliser "chilled" projectiles (of which more particular mention will be made hereafter), induced the authorities to give a trial to some solid spherical "chilled" iron projectiles, some of which still exist.* The chilled *spherical* projectiles were far from satisfactory. Their form was unsuitable to the brittle material, but it was thought that they were somewhat more effective than ordinary cast-iron, and they were not more expensive. The fact is, that no spherical shot are very effective against thick armour-plates —at least, any effect which may be accomplished can only be obtained at a disproportionate expenditure of power, and then only at very short ranges. No smooth-bore gun can compare with a rifled gun for penetration; because with the rifled projectile, if the weight of shot be equal to that of the sphere, the diameter will be less, and if the diameter be equal, the weight will be more; and we thus have either less work to do, and equal power to do it, or equal work to do, and more power to do it. To this must be added that the pointed form of head is far more favourable to penetration than is the hemispherical surface with which the spherical shot strikes the plate. Hollow shot were used by the navy against wooden ships at short ranges, in order to produce a greater splintering effect, and to carry more fragments into the vessel. They could not be used effectively at long ranges on account of their lightness. Of late years empty shells have been used as hollow shot when required; but at one time hollow shot constituted a separate projectile.

An application of small solid shot, weighing 1 lb. each, must not be omitted. They are thrown sometimes from a mortar, in charges of one hundred shot. The shot are piled loose in the mortar over the powder, a piece of wood being placed between the powder and shot; and against crowds of men huddled together, or a fleet of small boats, these *pierrier*† charges of pound-shot are very useful. Case-shot is used for firing at troops in masses at short ranges. They consist of cylindrical iron cases, filled with balls. The case is broken by the discharge, and its contents are driven forward in a conical shower to a distance of from 300 to 400 yards from the muzzle of the gun. When cavalry are charging home, or when troops present themselves within the range indicated, case-shot are terribly effective, and many a bold charge has been checked and many a gallant column thrown into disorder and panic by a well-directed discharge of these destructive missiles.

Grape-shot is intended for use on much the same sort of occasions as would be selected for the use of case, except that, being made up with heavier balls, its range is somewhat greater. It was also useful for cutting and destroying the rigging of ships in naval actions. Originally, grape consisted of a canvas bag filled with balls, piled round an iron spindle through the centre of the bag, the bag being drawn together between the balls, or "quilted" by a strong line. In this form the grape somewhat resembled a bunch of grapes—whence its name. For several years the quilted grape has been superseded by grape of a pattern known as the "Caffin" grape. This pattern consists of four horizontal iron plates, connected by a spindle through the centre, and having three tiers of shot arranged between the plates. The advantages of this pattern are, that it is less perishable than the old-fashioned grape, the bag and cord of which were liable to rot and fall to pieces; that it is more portable, as it can be carried in pieces, and put together when required; and that the parts are interchangeable. During several years past the manufacture of grape has ceased, it being considered that case-shot will answer all the purpose.

This completes the list of shot for smooth-bore guns. We will give in our next paper descriptions of the various shells and other projectiles used with this class of ordnance.

* We reserve for the present such remarks as suggest themselves in connection with chilled projectiles, until we come to speak of the Palliser shot and shell.

† From the French word *pierre*, a stone—from a number of having been in early days fired in this way instead of shot.

TECHNICAL DRAWING.—XXV.

DRAWING FROM ROUGH SKETCHES (*continued*).

FIG. 239 is half the elevation, and Fig. 240 is a vertical section of an equilibrium valve. Valves of this description are used in engines of large dimensions, such as those for pumping in Cornwall.

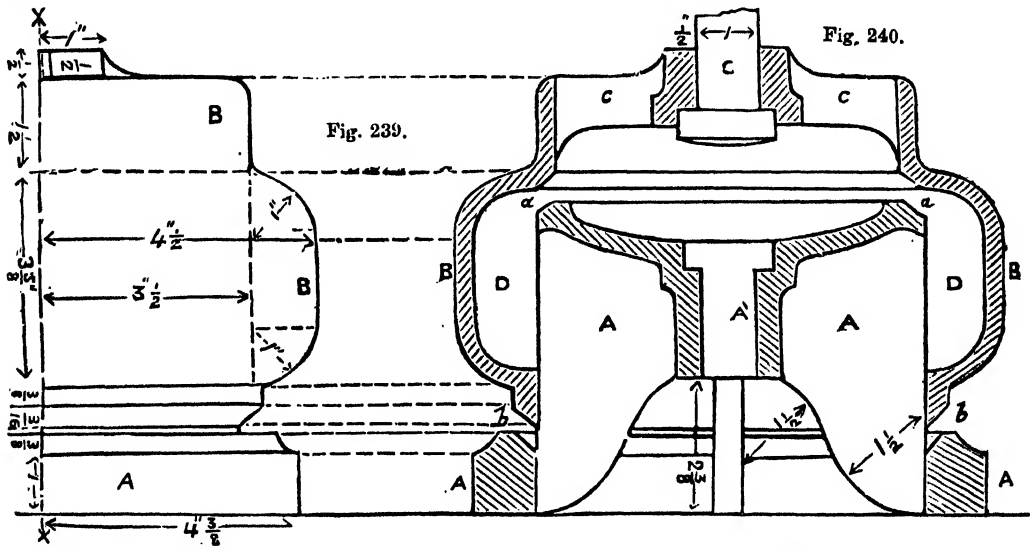
In these valves a large extent of opening for the passage of steam is given with very little traverse, whilst very little power is required to work the valve.

In the example here shown, A is the fixed seat, made of cast-

by a rod, C.

The contact of the valve with its seat takes place at two places, *a* and *b*, which are formed into accurate conical surfaces, the one, *a*, being internal, and the other, *b*, external.

When the valve is closed, these surfaces coincide with similar ones on the seat, and when it is lifted, as shown in Fig. 240, two annular openings are simultaneously formed; thus giving a double ingress or egress, as the case may be, to the steam, which enters at, or issues through, the upper opening, *a*, through the central part, D, formed in the valve-piece, B.



The rod or spindle, C, of the valve, B, is fixed to a centre-eye cast in one with the valve-piece, and connected to it by four arms, two of which are shown at *c c*. Of the other two, which are at right angles to these, one is hidden by the rod C, and the other has been cut off by the plane of section.

The seat is similarly formed with four arms, or deep feathers having an angular ring at the base, the top edge of which is bevelled and ground to fit the lower edge of the valve B, and when lifted, forms the opening shown at *b*.

The student will do well to draw the whole of the elevation (Fig. 239), of which only half is given in the plate; but as the object is perfectly symmetrical, there will be but little difficulty in doing this.

Having drawn the centre line, X X, set off on each side $4\frac{3}{8}$" for the width of the fixed seat, A, erect perpendiculars, and make the seat 1" high.

The chamfered edge of the fixed seat is $\frac{3}{8}$ high. It will be seen that no measurement is given for the space above it, because this is variable, being the aperture shown at *b*, which would be increased if the valve-chamber, B, were raised further, or would be closed altogether when B descends; the depth, however, of the bevelled edge of B is $\frac{3}{16}$.

Next follows a vertical rim, and $\frac{3}{8}$ from this the widest part of the valve-chamber starts by means of a portion of a quadrant of 1" radius, the width of the chamber being $3\frac{1}{8}$" in the upper part, and $4\frac{1}{2}$" in the middle, the height of the wider portion being $3\frac{3}{8}$", and of the narrow, B, $1\frac{1}{8}$", the arms rising to a central boss $\frac{1}{4}$ inch higher.

It is hoped that these measurements having been given, the student will be enabled to complete the figure, and also to draw the section.

The two drawings may be placed next to each other, as in our example, in which case all the vertical measurements for the exterior of the section may be projected by simply carrying out the horizontal lines. Or the section may be placed under the elevation, in which case the measurements for the widths will be obtained by drawing perpendiculars from the widths as set off in the elevation. These two examples should be drawn to the scale of $\frac{1}{2}$ an inch to an inch.

It is now deemed desirable to give the student another course of lessons in projection, and for this purpose the first subject selected is a bent cylinder.

Fig. 241.—Let A B, C D represent a quarter of a cylindrical ring, the centre of which is at O.

Now if this quarter-round were cut across the middle by a plane radiating directly from the centre—viz., O O′—and the upper half were rotated on a pivot at E, the cylinder would take the bent form represented in the figure, for D would be moved to D′, and B to B′.

Fig. 242.—The plan of this object is very readily obtained, for it will be clear that A C rests on a circle, and that B′ D′ being the diameter of a circle equal and parallel to A C, and seen under precisely similar circumstances, will be represented in plan by the circle D″ B″. The diameters F G and H I being connected by the lines F H and G I, the plan will be completed.

It is, however, necessary to add the plan of the section at J K.

Now it is evident that this section is really a *circle* of precisely the same diameter as the other two, therefore a perpendicular drawn from E will cut G I and F H in L M, which will be the diameter.

But the section is not horizontal, and therefore its plan is not a circle, but an *ellipse*, of which the short diameter is the line N O, obtained by drawing perpendiculars from J and K.

To find additional points in the ellipse, divide one of the circles into any number of equal parts, as P, *p*, Q, *q*, and carry up perpendiculars to cut the elevation in the points lettered P′ *p*′, Q′ *q*′. From O′ describe arcs through these points, cutting the section-line J K in P″, Q″.

From these points draw perpendiculars, and from P, *p*, Q, *q* in the circle draw horizontals intersecting them in P‴, Q‴, *p*‴, *q*‴. The one half of the ellipse is to be traced through the points, and the other half is to be obtained in a precisely similar manner.

To find the curves caused by a cylinder penetrating a sphere, the centre of the sphere not being situated in the axis of the cylinder.

Let A B (Fig. 243) be the plan, and A′ B′ (Fig. 244) the elevation of the cylinder; and let C D be the plan, and C′ D′ the elevation of the sphere.

Draw the tangent E F, which will be the plan of the vertical circle which would touch the cylinder; in other words, if a knife were passed through the sphere close to the cylinder, it

From H (Fig. 243) draw a perpendicular cutting the diameter of the sphere in the elevation in H′, then with radius O H′ describe the required circle.

The plan H I of this circle shows that it is cut through by the cylinder in J and K.

Therefore, from J and K draw perpendiculars cutting the

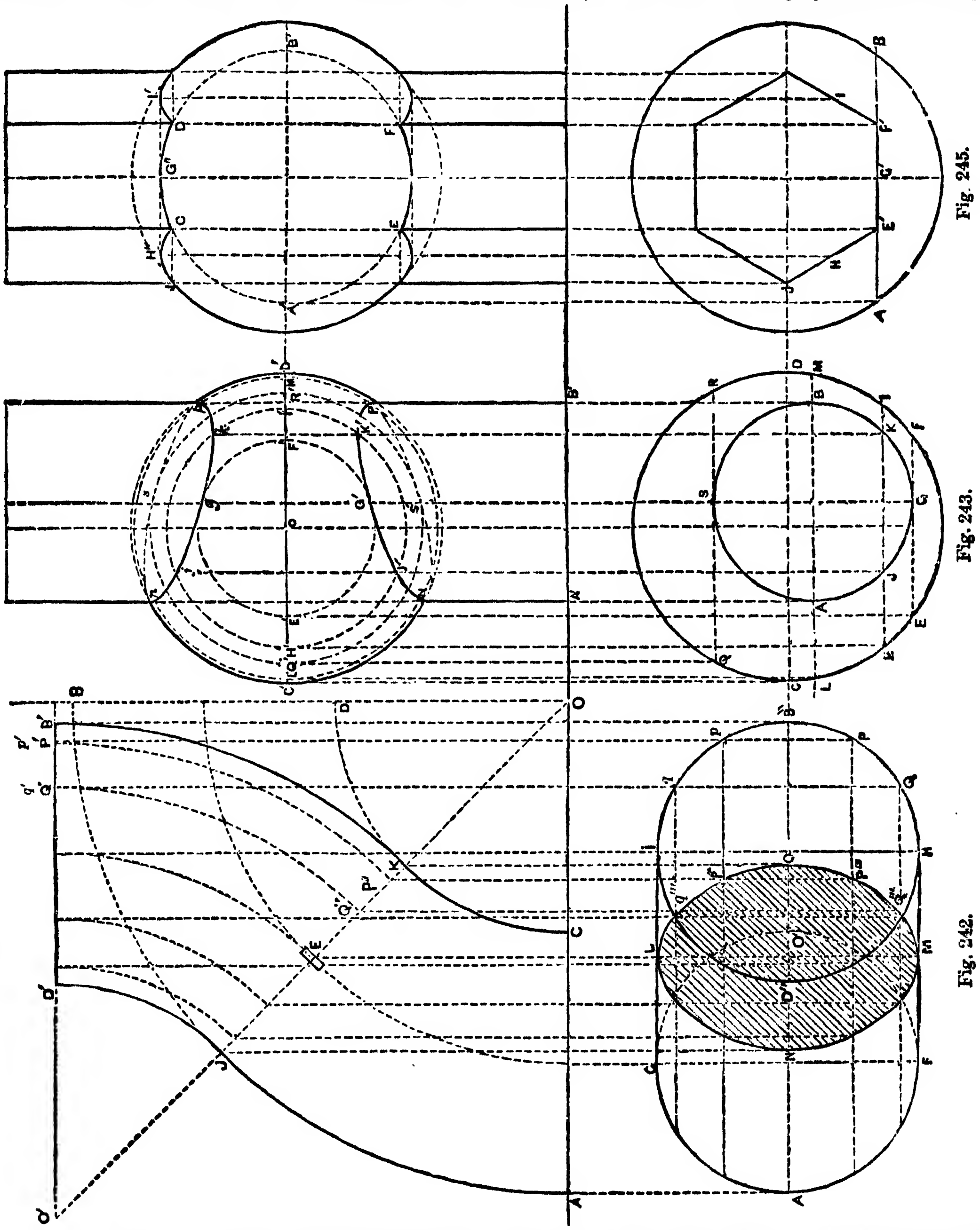


Fig. 246. Fig. 245. Fig. 244. Fig. 243. Fig. 241. Fig. 242.

would leave a section which would be the circle E′ F′, which may be projected from the section-line E F in the plan.

Now this plane, as seen in the plan, touches the cylinder at the point G, and a perpendicular raised from this point will cut the circle E′ F′ in G′, g.

Again, it will be clear that all the sections of the sphere parallel to E F will be circles. Therefore draw H I, which will be the plan of a circle passing through both cylinder and sphere.

circle O H′ in J′ and K, and also in two points immediately above them, j and k. Pursuing the same method, the diameter of the cylinder produced will give the plan L M of the circle L′ M′, which the perpendiculars forming the elevation of the cylinder cut in N, n, P, p.

Similar points may be found for the back curve. It will be sufficient to show one. The line Q R represents the plan of the circular plane which would touch the cylinder on the opposite side, and parallel to E F.

This being projected, gives in the elevation the circle Q′ R′, which is cut by the perpendicular drawn from S, in the points g′ and s.

The upper and lower curves of penetration are then to be drawn through the points thus obtained.

.. 245 is the plan and Fig. 246 is the *elevation of a sphere penetrated by a hexagonal prism*. Draw the complete plan, and project the elevation of the prism and the external form of the sphere from it.

The last study will have rendered it clear that the plane of which A B is the plan, will in its elevation be the circle A′ B′, and therefore the curve of penetration on all the sides of the prism will be portions of a similar circle.

Thus the extremities of the arcs C D and E F are the points where the perpendiculars from E′ F′ cut the circle.

The curves on the sides of the hexagon are projected in the following manner:—

Draw perpendiculars from the middle points, H and I, of the sides, and intersect these by a horizontal from G″, the highest point in the arc; then the curve is to be traced through C H′ J. The corresponding curves will be obtained in a similar manner.

COLOUR.—VII.

By Professor A. H. Church, M.A., Royal Academy.

THE CULTIVATION OF THE SENSE OF COLOUR—TRIPLE COMBINATIONS OF COLOUR—DISTRIBUTION, BALANCE, AND QUALITY OF COLOUR.

Having described with some fulness of detail the relations of colours amongst themselves and to white, black, and grey, we may now extend and apply the knowledge gained to some of its practical uses of a decorative kind. Directly we begin to study combinations of three or more colours, and the important subjects of the harmony, contrast, and balance of colours, we find our ground less sure, for not only do many subjective influences come in to modify the objective realities of complex colour-combinations, but the element of *taste*—to some extent a personal element peculiar to the individual—introduces fresh difficulties in reaching a right judgment. Yet it must not be forgotten that taste in great measure depends upon knowledge, association, and culture, and may be developed from very small rudiments by proper study. Never was there a time when the opportunities for such study, in relation to taste in colour, were more abundant. Commencing with the acquirement of the knowledge of the theory and the laws of light and colour, we may proceed to study and to analyse the most pleasing and attractive colour-combinations to be found in the works of Nature and of art. Here it is that our parks and gardens, our museums of specimens of natural history and ornamental art, as well as such art libraries as that at South Kensington, become of such special use. The dwellers in a great city, if shut out from the pure blue of the sky, and the foaming white of the ocean, if debarred from the wide beauties of the open landscape, yet have an opportunity of studying the wonderful colours of Nature. Such are shown in the softened tones, and tender hues, and metallic lustres of flowers, birds, shells, and minerals, in the pictures which represent outward facts as interpreted by the intelligence and skill of man, and in the thousand and one forms of decorative art which so often express, in various degrees, the development, historical and national, of the appreciation of colour.

We may suitably commence to apply the laws of colour by a reference to the effect of certain triple combinations of primary and other colours. Some details of this kind have been already furnished when we were describing the value of black and white in separating related colours. Orange and red do not accord well together, for they are closely related by the possession of many qualities in common, being bright, warm, and exciting to the eye, and so similar as to have their boundaries confused when placed together. A white line placed between a red and an orange space or device of colour not only serves to separate them, but to deepen and enrich their tone, by virtue of the law of contrast. But it does not do this so effectually as a line of black, which, affording very nearly the strongest possible contrast with orange and a powerful contrast with red, brightens both of these colours considerably, without actually causing the whole combination to reflect more light to the eye, but rather less. Now if we wish to separate two related colours from each other by the use of white or black, and these colours should happen to be, like blue and violet, of a cool retiring quality, and less exciting than orange and red, black will prove itself much inferior to white. Deep tones of blue and violet are so closely related to black that the latter effects little towards their separation, while it is itself injured by contact with them, acquiring a rusty hue. But white, on the other hand, while it deepens these colours, renders them purer, and by itself acquiring a faint tinge of the complementary yellow or orange (in obedience to the law of simultaneous contrast) causes their differences to appear more distinctly. Still there is a triple combination slightly preferable to that of blue, white, and violet; it is formed by the substitution of grey for white. The contrast becomes less violent, and is undoubtedly more agreeable. Without going through the whole series of primary and secondary colours in their relations to one another, and to grey, white, and black, it will be useful to furnish an outline of the principles by which such combinations may be classified and valued. Triple assortments of this kind may be arranged in three groups:—

1. Two primary colours, with (*a*) white, (*b*) grey, (*c*) black.
2. One primary and one secondary colour, with white, grey, or black.
3. Two secondary colours with white, grey, or black.

1. Of the first species of triple assortments there may be nine varieties, even if we limit the list to those varieties in which the colours are separated by the white, grey or black:—

Yellow—with white, grey, or black—and red	(three varieties).
Red—with white, grey, or black—and blue	(ditto).
Blue—with white, grey, or black—and yellow	(ditto).

2. Of the second species of triple assortments there may be twenty-seven varieties:—

Yellow—with white, grey, or black—and orange	(three varieties).
Yellow—with white, grey, or black—and violet	(ditto).
Yellow—with white, grey, or black—and green	(ditto).
Red—with white, grey, or black—and orange	(ditto).
Red—with white, grey, or black—and violet	(ditto).
Red—with white, grey, or black—and green	(ditto).
Blue—with white, grey, or black—and orange	(ditto).
Blue—with white, grey, or black—and violet	(ditto).
Blue—with white, grey, or black—and green	(ditto).

3. Of the third species of triple assortments there may be nine varieties:—

Orange—with white, grey, or black—and violet	(three varieties).
Violet—with white, grey, or black—and green	(ditto).
Green—with white, grey, or black—and orange	(ditto).

In these lists we have presented the simplest kinds of triple assortments in their baldest forms. Before we can form any just idea of their relative merit, so far as the degree of pleasure they convey to the eye is concerned, it will be necessary to look a little more closely at the various conditions under which these assortments of colours may be made or met with. Supposing our colours to be produced by the purest pigments, and each one of them to present its characteristic depth of tone (which we have previously described as its *equivalent*), we shall yet find that the effect of any one of our series, above given, of simple triple colour-assortments depends upon many minute particulars. Amongst these we may name, as the most important, the relations of the colour-elements of each assortment, so far as concern their—

1. Distribution, as to form and surface.
2. Proportion or balance.
3. Quality, as to warmth, brilliancy, etc.

The consideration of the texture of the coloured material, its lustre, transparency, and similar physical character, together with the modifications of colour produced by different kinds of illumination, being deferred for the present, we proceed now to say a few words as to the distribution of the constituents in combinations of three colours. The simplest case is the presence of the three elements on three equal and similar spaces, such as a square space of yellow separated by a similar square space of white from one of red; or we may have a disc of red, surrounded by a ring of white, and that bordered by a second ring of yellow, each surface being of equal area. Differences of area, as well as of form, may also be taken into consideration. The white space may be reduced to a narrow band separating the yellow and red, or it may be increased so as to form

several strips, and then arranged in the order white yellow, white red, and so on. This is not only an alteration in the relative space occupied by one of the elements in a triple assortment, but it involves an alteration in the way in which the element is distributed. The mode of distributing colours, however, belongs rather to the subjects treated of in the "Principles of Design," although it undoubtedly influences to a great extent the quality of the colour-effects produced in any assortment of hues. We will, however, say a few more words about the effects of the mode of distributing colour on a surface when we have touched upon the two allied subjects of the balance of colour and the quality of colour.

The balance of colour has been already alluded to in Lesson IV., and has likewise been explained by the writer of the "Principles of Design."* The principle which underlies the idea of the balance or proportion of colour is that the eye and mind demand for their satisfaction the presence of the several elements of the chromatic scale in some form or other of combination, and in such proportions as shall be competent to re-constitute white light, whiteness, or greyness. But there are three facts which must not be lost sight of in studying the balance of colour in any actual composition. The first of these facts is that our purest pigments are far from representing the several colours of the spectrum, and so we can only approximate our groups of coloured surfaces very roughly to the proportions required by theory. The next fact is that this theory itself is merely a provisional one. For, as we have already pointed out (see "Colour," No. IV., page 211), Professor Maxwell and other observers have shown that the commonly received theory as to the primary colours is not altogether true or competent to explain some of the most important phenomena of colour. Convenient this ordinary theory certainly is, while its defects do not obtrude themselves upon our notice when we examine the impressions produced by coloured terrestrial objects. But we will not go over this ground again here, merely mentioning the inherent defectiveness of the usual theory of the coloured constituents of white light, in order to point out how it is that we feel unable to claim any real or complete scientific basis for our present views as to the balance of colour in a composition. We must, however, for the present accept and utilise these views in default of better; but it would be improper to claim for them an unhesitating acceptance or adoption. But even supposing the theory of the balance of colour to have greater pretensions to truth than it really possesses, there is a third fact which tends to lessen still further its value and applicability—we refer to the satisfactory and agreeable nature of many colour-combinations which glaringly transgress its demands. Yet the fact that the contemplation of a single pure and bright colour viewed alone gives us pleasure no more negatives the idea of the greater and more complex kind of pleasure derived from an assortment of colours than the sweet quality of a particular note in the human voice or a musical instrument disproves the superior beauty of a chord. So, too, just as some airs have but a very limited range of musical tones, yet possess a simple and quiet beauty of their own, so a few colour-tones of the same scale, or a series of three or four closely-related colours, may give us great pleasure, and seem to employ and satisfy the eye. There can be no doubt, then, that while the colour-elements are beautiful by themselves and in a large number of simple combinations, fresh beauties of other and less obvious sorts are brought out by assorting colours in obedience to certain principles. So far as balance or proportion is concerned, we may say that of the most brilliant and luminous colours, such as yellow, we need least in any assortment; of colours of intermediate power, such as red, a larger quantity may be used; while the deep and more retiring blue demands a space at least equal to that occupied by both the yellow and the red. White will be used most sparingly, as being more brilliant than yellow; and black will likewise be employed temperately, as the deepest of all tones, and giving the most violent contrasts possible. Here it is that the immense value of grey and the tertiary hues is especially felt. For suppose we desire to convey some particular impression by a colour-assortment, we can often do so, without widely departing from the balance of colour, by introducing grey into the assortment, either by itself or mixed with a colour, so as to produce a "broken tone." Thus, if we desire a quiet but not cold assortment of colours, we may mix with our yellow enough grey to turn it into citrine, and then the complementary violet, which in a binary assortment is the other necessary constituent, will not produce so striking a contrast as with the original yellow. We may, also, then increase the proportion of surface covered by the citrine, so as to lighten the whole effect. In such a combination, white, too, may be introduced with more satisfactory effect, as it accords better with yellow when the latter has been made less brilliant by admixture with grey than it does with pure yellow, which too much resembles it in brilliancy. In considering the balance or proportion of this or any such arrangement, or of those arrangements in which there is a manifest deficiency of some one colour-element, it should not be forgotten that we have continually occasion to devise combinations of colour which are *not intended to stand alone;* indeed, it is usually impossible, even if it were desirable, to isolate the colour-assortments of natural or artificial origin. Thus the very elements which may be needed to supply the chromatic balance in, say, an old blue and white jar of the porcelain of Nankin may be furnished by the deep brown stand on which it is placed, or by the furniture or paper of the room. We must not, then, expect in all the fixed or movable decorations of a house that perfectly balanced proportion which the whole of them taken together may offer. The position, use, and material of each coloured object will necessitate a particular preponderance of certain colours, while a perfect colour-balance in each part would constantly lead to a very imperfect one in the whole system or arrangement.

Something has already been said of the quality of colours, as influencing our estimation of the value of their several assortments. We here return for a short space to this subject. In describing the primary and secondary, we have shown that their fullest and purest tones differ greatly in different cases. No tone of yellow can be obtained of equal depth with the corresponding tone of blue. The brightness or brilliancy of the yellow will always cause it to contrast, not only so far as the tone is concerned, but also in relation to colour, with the blue. To deepen the yellow we must mix black with it, turning it into brown. Colours such as green and red may be obtained of full tones and yet equal intensities, so as to offer no contrast of tone, only one of colour. The inherent brightness or sombreness of colours forms, then, one of their most important qualities when they are introduced into combinations or assortments. Of course, the quality of colours is variously modified by admixture with other colours, or with white, grey, or black. Combinations of secondary and tertiary colours and hues, while influenced by the same principles of distribution and balance as those just laid down, are less capable of yielding discordant and unsatisfactory assortments. The contrasts between them are less violent, while their assortments admit of more varied treatment and more subtle expression. We shall have occasion to notice the great value of several of the more indefinite and mixed hues in the remaining papers of this series.

* TECHNICAL EDUCATOR, Vol. I., p. 221.

BUILDING CONSTRUCTION.—XIII.

JOINTS IN TIMBER (*continued*).

IN the present lesson we continue the instructions commenced in our last for joining pieces of timber together. The importance of ascertaining the best methods by which separate pieces of timber may be joined together so as to present the greatest amount of resistance to pressure, whether vertical or lateral, cannot be insisted on too much, for it is clear that considerable injury might result from the adoption of a defective mode of making a joint. It is in cases of this kind that technical education becomes so strikingly apparent. Of two kinds of joints, one of which presents certain mechanical advantages, an unskilled or rather untaught workman will select that joint which happens to suit his fancy, while the skilled workman will at once adopt that which he can see will be most effective from a mechanical point of view.

Fig. 105 shows a mode of lengthening timber, first by means of *halving*, and additionally by a *dovetail*. This joint is supposed to be supported from below, as in the case of a wall-plate, etc. The dovetail gives this joint power to resist any tension which

might tend to pull the parts asunder, and also strengthens it against lateral pressure.

Figs. 106 and 107 are two forms of scarfing which are very generally used. The principles of scarfing having been fully explained, it is not necessary to repeat them here. Fig. 107 shows the "sally," or point given to the end of each part to resist lateral pressure, the sally at the end must be formed by a very obtuse angle, and the edge of the points, and of the parts which receive them, must be worked very true, or there will be a chance of the wood being split by vertical pressure.

Figs. 109 and 110 are joints used for lengthening timber when supported by columns or walls.

We now proceed to speak of joints properly so called.

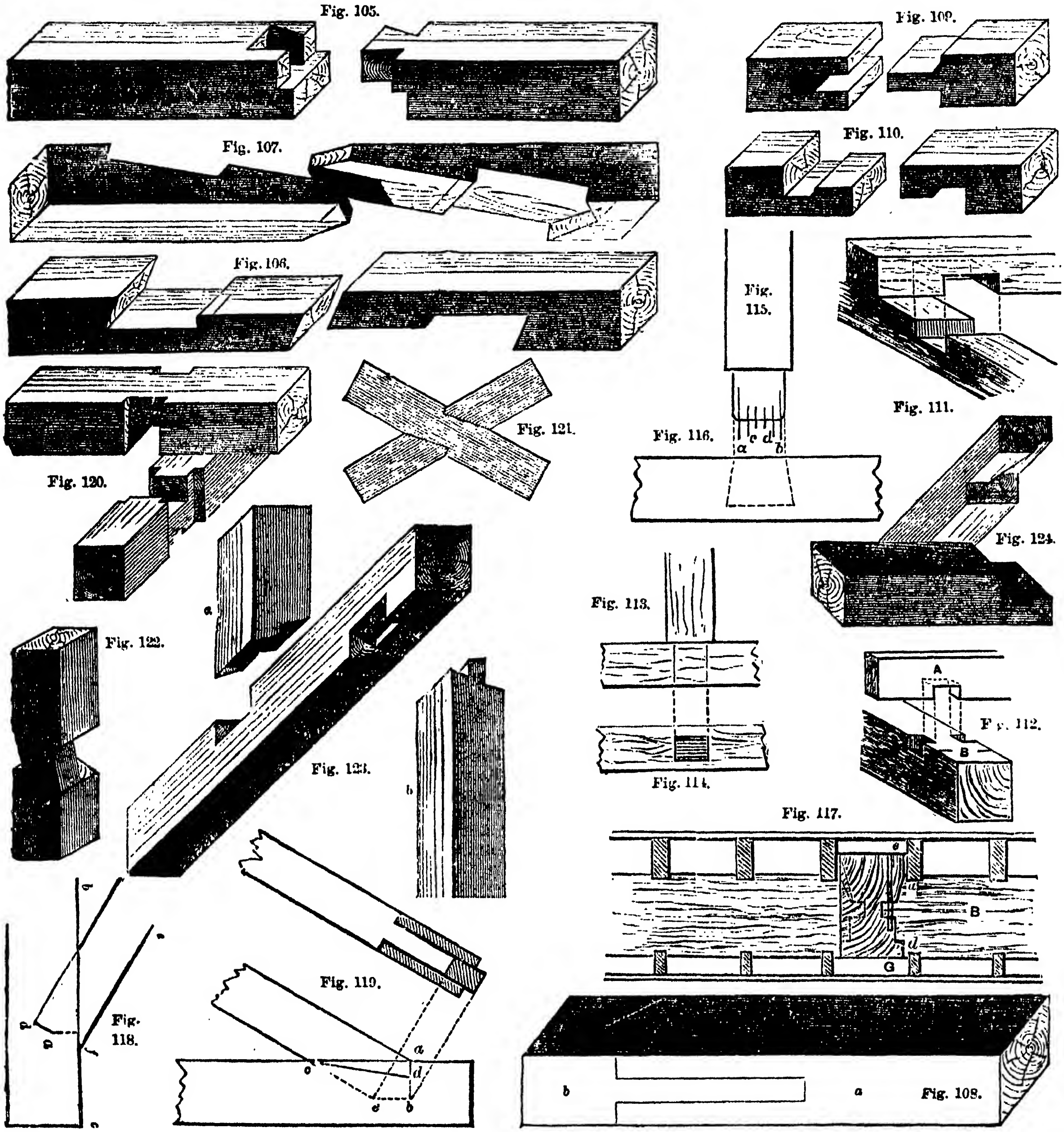


Fig. 105. Fig. 106. Fig. 107. Fig. 108. Fig. 109. Fig. 110. Fig. 111. Fig. 112. Fig. 113. Fig. 114. Fig. 115. Fig. 116. Fig. 117. Fig. 118. Fig. 119. Fig. 120. Fig. 121. Fig. 122. Fig. 123. Fig. 124.

Fig. 108 is a joint effected by a tongue or tenon in the one part (*b*) fitting into a mortise or slit of similar width in the other (*a*). This is considered a very good joint when the beam so joined is supported by a column underneath the joint. In such cases it may be placed on its narrow side, so that the [illegible] of the tongue may be vertical. The sides of the part *a* then strengthen the beam against lateral strain. This method, too, is found very effective when used vertically, there being no possibility of the parts slipping over each other. In this case

Where two pieces of timber of equal thickness cross each other, and the joint is to be *flush*—viz., the pieces when joined are to form a flat surface—they are *halved* together; that is, a piece is taken out of each of half its thickness and of the breadth of the piece which is to cross it, and thus the one drops into the other, as shown in Fig. 111, and pins are then driven through both.

When a joist is to rest on a girder, the joint is said to be "notched in" (Fig. 112), pieces of an oblong form being taken

out of the opposite upper edges of the girder or lower joist, and a piece (A) is taken out of the lower edge of the upper timber equal to the piece (B) left standing in the middle of the girder. The upper one then drops into the notches.

When the beams stand square with each other, and the strains are also square with the beams, and in the plane of the frame, the common mortise and tenon is the most common junction. This is shown in Figs. 113 and 114, and will not require any explanation. A pin is usually put through the joint in order to counteract any force which may tend to separate the pieces. Every carpenter knows how to bore the hole for this pin, that it shall have the tendency to draw the tenon tightly into the mortise, thus causing the shoulder to butt closely without the risk of tearing out the piece of the tenon beyond the pin if he draws it too much. Square holes and pins are by far preferable to round ones for this purpose, bringing more wood into action with less tendency to split it. A joint of this kind often used is that called "foxtail joint," the peculiarity of which is that the mortise (Fig. 116) is not cut *through* the wood, and still the tenon is firmly wedged in. The mortise is cut wider at the bottom than at the top; the end of the tenon (Fig. 115) is then slightly split in several places, and wedges of hard wood are inserted; the tenon is placed in the mortise, and the piece driven in with the mallet. As the broad ends of the wedges are forced against the bottom of the mortise they split the end of the tenon, which thus spreading out fills up the wider part of the cavity. In order to prevent the wedges splitting the piece beyond the shoulder, the outer wedges placed near the edge of the tenon should be very thin, and project further than the others; the succeeding pairs should be rather thicker as they follow inward, and should stand out from the end less and less. Now it will be clear that *a* and *b* will touch the bottom first, and as they come into action will split off a very thin slice, which will bend without breaking; the wedges *c* and *d* will act next, and will have a similar effect; thus, the rest, as they come into operation, will be prevented splitting the tenon further than is required. The thickness of all the wedges added together should be equal to the difference between the width of the mortise at the top and at the bottom.

The binding joists of a floor are mortised into the girder. In this case the tenon should be as near the upper side as possible, because the girder would, in the event of its yielding to any strain, become concave on that side; but as this exposes the tenon of the binding joist to the risk of being torn off, it is necessary to mortise lower down. The form of mortise (illustrated in Fig. 117) usually given to this joint is extremely judicious. The sloping part, *a*, gives a very firm support to the additional bearing, *a d*, without much weakening the girder. This form should be adopted in every case where the strain has a similar direction; *c* is a pin driven in from the top of the girder through the tenon, which gives it additional security.

The joint that most of all demands careful attention is that which connects the ends of beams, when one pushes the other very obliquely, putting it into a state of tension. The most familiar instance of this is the foot of a rafter pressing on the tie-beam.* When the direction is very oblique (in which case the extending strain is the greatest), it is difficult to give the foot of the rafter such a hold of the tie-beam as to bring many of its fibres into the proper action. There would be little difficulty if we could allow the end of the tie-beam to project a small distance beyond the foot of the rafter; but, indeed, the dimensions which are given to tie-beams for other reasons are always sufficient to give enough abutment when judiciously employed. This joint is, unfortunately, much subject to failure by the effects of the weather. It is much exposed, and frequently perishes by rot or by becoming so soft and pliable that a very small force is sufficient either for tearing the filaments of the tie-beam or for crushing them altogether.

Long tenons to the ends of rafters are not now so much used as they formerly were. They have been observed to tear up the wood above them, and thus to push their way to the ends of the rafters. Carpenters, therefore, now give to the toe of the tenon a shape which abuts firmly in the direction of the thrust on the solid bottom of the mortise, which is well supported on the under side by the wall-plate. This form, which is represented in Fig. 118, has the further advantage of having no tendency to tear up the mortise. The tenon has a small portion (*a*) of its end cut perpendicular to the surface (*b c*) of the tie-beam, and the rest (*d*) is perpendicular to the length (*e f*) of the rafter.

Fig. 119 is another form of tenon for the foot of rafters. Here the whole thickness of the rafter is brought into service, and the end *a b*, cut so as to make a right angle with the surface of the tie-beam, is sunk into it, the line *c* gradually slanting down to *d*; the tenon *c d b e*, then, whilst it is the whole length of the part of the rafter entering the tie-beam, is only a part of its thickness; and, as will be seen in the illustration, the end of the rafter and tenon, *a b*, forms a perpendicular with the upper surface of the tie-beam, whilst *b e* is at right angles to *b a*.

This joint is common on the Continent, but has been objected to by some carpenters on the ground that, should there be any shrinking in the king-post which should allow it to sink, the rafter would turn on the point *c*, as on a pivot, and the point *b*, describing an arc, might push up the wood above it; but this does not seem very likely. It is quite impossible, within the limits of the present lesson, to dwell longer on this department of woodwork; but enough has been said to give important aid to the student of that branch of Building Construction. The joints by which the ends of rafters abut on the beams are often bound by iron straps. These will be shown in the illustrations connected with roofs.

Fig. 120 shows a joint of a similar character to Fig. 111, but more complex in its working. It is not adapted for large works, being still more weakened by the cutting away of the pieces at the side.

Of course, the joint is only half as strong as the timbers originally were, owing to half the thickness of each being taken out. If, therefore, they are of any considerable length, the joint must be supported.

Fig. 121 shows the method of halving when the timbers cross each other at any angle, and Fig. 122 is a separate view of one of the parts.

Fig. 123 exhibits two methods (*a* and *b*) in which timbers can be united at right angles to each other when they are not to cross. These illustrations are too plain to need any explanation.

Fig. 124 is one of the numerous methods for uniting timbers at an angle of a building by means of a dovetail joint, by which means the end of each is locked into the end of the other.

ELECTRICAL ENGINEERING.—XIV.

BY EDWARD A. O'KEEFFE, B.E., A.S.T.E.,

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MEASURING INSTRUMENTS.

In order to make a reliable measurement of the strength of current flowing in any circuit, it becomes a matter for consideration which of the effects which the current is capable of producing shall be utilised for making the necessary determination. The three properties of the current which are made use of for measuring its strength are:—

The chemical property, or the power which a current possesses of decomposing certain liquids through which it passes into their constituent elements. This phenomenon is called Electrolysis.

The magnetic property, or the power which a current possesses of deflecting a pivoted or suspended needle placed in its vicinity, and obliging it to take up a definite position depending on the strength of the current.

The heating property, or the power which a current possesses of heating a wire through which it passes.

CHEMICAL METHOD.

The copper voltameter.—From trustworthy experiments, it has been found that if a current of one ampère passes through a solution of sulphate of copper for one second, it will deposit ·000329 gramme, or ·005084 grain, of pure copper on the electrode which leads the current out of the liquid. The same quantity will be deposited by a current of $\frac{1}{10}$ ampère flowing for ten seconds, by $\frac{1}{100}$ ampère flowing for 100 seconds, or by

* The parts to which these names apply will be found in a future lesson.

10 ampères flowing for $\frac{1}{10}$ second; in other words, the amount deposited is proportional to the strength of the current, and to the time during which the current has been flowing.

For any case—

Let W = the weight in grammes of the metal deposited,
,, C = the current in ampères,
,, t = the time in seconds during which the current has been flowing;

$$\text{Then} \quad W = C \times t \times \cdot 000329,$$

$$\text{or} \quad C = \frac{W}{t \times \cdot 000329}.$$

We can thus measure the strength of the current by weighing the metal deposited by it, and noting the time during which the operation has continued. The apparatus used for performing this experiment is called a *voltameter*. The current is led into and out of the liquid by two square copper plates called *electrodes*. The plate by which the current enters the voltameter is called the *anode*; that by which it leaves it the *kathode*. They are fixed in the liquid parallel to one another, at a distance of about half an inch apart, and the size of each plate should be so regulated as to expose an area (on each face) of at least two square inches for every ampère passing through the voltameter. If the plates are smaller than this the copper will be deposited too quickly, and, instead of forming a firm film on the kathode, will be in a loose condition, liable to be partially washed off when the plate is removed for weighing. The kathode should be made of a very thin sheet of hard copper, so as to expose a large area, and to introduce the smallest possible error in determining its increase in weight. Before commencing the experiment the plates should be thoroughly cleaned by washing them with water and silver sand, and rinsing them with distilled water, carefully avoiding touching them with the hands, which are always more or less greasy. They should then be heated and weighed. The plates should consist of pure copper which has itself been deposited electrically.

The solution should be made up of distilled water and chemically pure crystals of sulphate of copper. It should be very slightly acid, and should have a density of about 1·15.

The silver voltameter.—The deposition of silver can also be used for measuring currents. It is advisable to deposit it in a platinum bowl which has been subjected to the same cleansing process as the copper plates. The area of the surface on which the silver is deposited should be about three times as large as in the case of copper for the same current.

The solution consists of nitrate of silver and distilled water, in the proportion of three ounces to the pint. The weight of silver deposited by one ampère flowing through this solution for one second is ·001118 gramme. The silver has the advantage over the copper voltameter, that the weight of metal deposited by the same current is considerably greater, and hence the increase in weight can be more easily determined with accuracy. At the same time, greater care must be given to the cleansing of the metal before commencing the experiment, as any grease on its surface may seriously interfere with the quality of the deposit, and make it loose and friable.

The kathode consists of a thick silver disc placed horizontally in the bowl, equidistant from the sides and bottom. It should be wrapped in a piece of filter paper, to prevent any loose particles which may be detached by the current from falling on to the bowl, and thereby increasing its weight. After the experiment the bowl should be first rinsed with distilled water, then with alcohol, then with ether, and finally dried over a spirit lamp before being weighed.

A platinum bowl is used in preference to a silver one, because the deposited silver can be re-formed into silver nitrate by the addition of nitric acid, which does not act on the platinum, and the bowl is reduced to its original condition and weight. Had a silver one been used, the deposit should be allowed to remain on it, and the bowl would, after a few experiments, become too heavy to be used with any degree of accuracy.

It is clear that this method is not suitable for measuring currents under ordinary commercial circumstances. Still, it is almost invaluable for standardising instruments which give direct indications of the currents passing through them.

The voltameter furnishes us with a thoroughly reliable method for accurately measuring currents of moderate strength, but for measuring either very small or very large ones it is almost useless unless very special precautions are taken to insure accuracy.

The instruments used for measuring currents are divided into two classes, according to the strength of the currents they are intended to measure. Those used for measuring large currents are called *ampère-meters;* those used for measuring small currents are called *voltmeters.* An ampère-meter is essentially an instrument of extremely low resistance through which the whole or a definite proportion of the whole current flowing in the circuit passes. Its resistance should be so small that when it is introduced into the circuit the total resistance of the circuit should not be appreciably increased. A voltmeter, on the other hand, is essentially an instrument of high resistance which is connected to two points of a circuit between which we require to know the E.M.F. that is working. Its resistance should be so high that when it is joined up in the circuit the distribution of the E.M.F. should not be appreciably changed, or, what is the same thing, the total resistance of the circuit should not be appreciably decreased.

A good ampère-meter, which is to be used for ordinary commercial work, should fulfil as many as possible of the following conditions:—

1, It should be direct-reading; *i.e.*, its indications should be read in ampères directly;

2, It should be dead-beat; *i.e.*, it should give its true reading directly the current is passed through it;

3, It should be portable and not liable to get out of order;

4, The accuracy of its readings should not be dependent on the strength of so-called permanent magnets, or on the earth's magnetic field;

5, Its readings should not be influenced by the presence of powerful magnets in its vicinity;

6, It should measure accurately, alternating as well as continuous currents.

No instrument at present in the market fulfils all these conditions, and few, if any, fulfil condition No. 6.

In every instrument there is at least one moving part which is acted upon by the current passing through the instrument. This part must be controlled by some force acting against the current and tending to keep the moving part in its zero position. In the instruments which have come into general use, this controlling force is derived either from a spring, permanent magnets, or gravity.

SIEMENS' ELECTRO-DYNAMOMETER.

In this instrument the controlling force is supplied by a spiral spring, which is balanced against the force exerted by one portion of the current in the movable part on another portion of the same current in a fixed coil.

Fig. 31 gives a perspective view of Siemens' electro-dynamometer. A wooden base containing three levelling screws supports a vertical wooden frame which carries the working portion of the instrument. The spiral spring, F, is fixed at its upper end to a milled head which carries a pointer, and at its lower end to the movable part, W W. This movable part consists of a single rectangular turn of wire, the ends of which dip into mercury cups, and which is supported by a thread which passes through the spiral spring. This movable part (or coil) has attached to it a pointer, Z, which should always point to zero on the scale, T. The fixed coil, A A—which, when the instrument is being used, has its plane at right angles to the movable one—is really made up of two coils: one, consisting of thick wire, is used for strong currents; and the other, consisting of thinner wire of five times as many turns, is used for weaker currents. The thick coil is attached between the terminals 1 and 3; the thin one between the terminals 1 and 2. A plumb line at the right-hand side of the instrument serves to show when it is level.

When this instrument is used for measuring a current it must first be levelled and then fixed so that the plane of its movable coil is at right angles to the earth's magnetic field—that is to say, the plane of the fixed coil should lie in the magnetic meridian. Both the pointer attached to the spiral spring and that attached to the movable coil should now point to zero on the scale, otherwise the instrument will be out of adjustment, and must be put right by unscrewing the pinch-

screw which fixes the pointer to the milled head, and turning the pointer till it comes to zero, taking care not to move the spring at the same time. The current flows through the fixed and movable coils in series, connection being made between them by means of the mercury cups into which the ends of the movable coil dip. The force exerted by the current in the two coils tends to make the movable one turn into the same

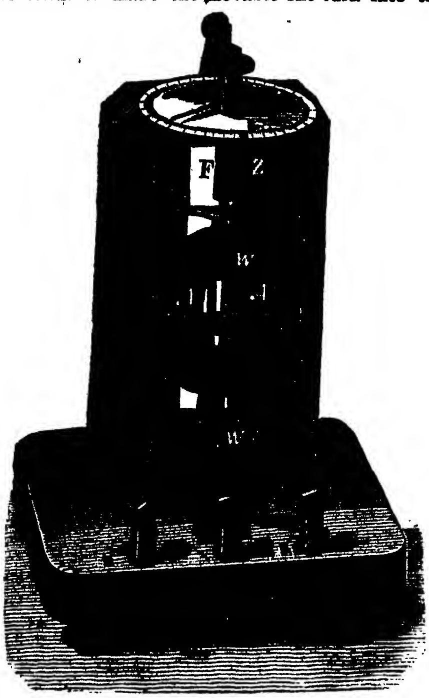


Fig. 31.—SIEMENS' ELECTRO-DYNAMOMETER.

plane as the fixed one, but this movement is controlled by the torsion of the spring. The milled head is now turned so as to oppose the force of torsion to the electro-magnetic force acting between the two portions of the current, and the turning is continued till the movable coil again points to zero. When in this position the force exerted by the current on itself is balanced by the torsion of the spring, and the angle of torsion is registered by the pointer attached to the milled head. The force exerted by the torsion of the spring is proportional to the angle through which the spring is turned, and the force exerted between the two portions of the current proportional to their product—*i.e.*, to the current squared; therefore, using symbols,

Let C = the current in ampères,

,, D = the angle of torsion in degrees,

then $C = K\sqrt{D}$,

where K is a constant which can be determined by comparing the instrument with the copper or silver voltameter, and which is called *the constant of the instrument.*

THE STEAM-ENGINE.—VI.

By J. M. Wigner, B.A., B.Sc.

THE CYLINDER (*continued*)—STUFFING-BOX—SLIDE VALVES.

When the cylinder is cold, as at starting, a portion of the steam condenses on its inner surface, and settles as water in its lower part. This, if allowed to accumulate, would very materially interfere with the working of the engine. "Blow-off cocks" are therefore introduced to carry off the condensed water, and through these some of the steam is allowed to escape. They should be opened for a little time when starting the engine, until the cylinder becomes thoroughly heated. Almost all condensation will then cease, and they should at once be closed again. If the cylinder is exposed to the air, it loses heat by radiation, and therefore the amount of condensed water is largely increased. This waste may, however, to a very great extent, be obviated by jacketing the cylinder—that is, covering it with some non-conducting substance, which prevents the radiation of the heat. Felt or some similar material, is usually employed for this purpose, and outside this strips of wood are placed, and held in position by brass bands, which give a finished appearance to the whole.

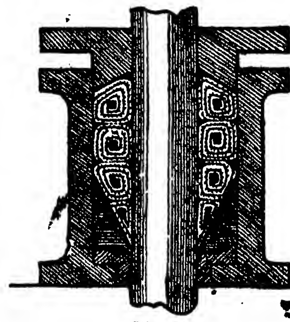


Fig. 28.

The under side of the piston is sometimes nearly or quite even; more commonly, however, it is considerably hollowed out, to allow the nuts for adjusting the packing-springs to be got at easily, or else the end of the piston-rod projects a little way where its nut is screwed on. In these cases the lower end of the cylinder is so shaped as nearly to fit it, and thus to obviate an unnecessary waste of the steam. The interior round the ports is also cut away a little, so as to allow the steam to pass below the piston when the latter is at the end of its stroke. Were it not for this, the piston would completely cover the port, and thus the engine would not act unless the fly-wheel had sufficient momentum to raise the piston a little way, and allow an entrance for the steam.

In the centre of the cylinder-cover an aperture is cut for the piston-rod to pass through, and this has to be packed, so as to allow of the rod moving up and down without excessive friction, but at the same time to prevent any leakage of the steam. This is accomplished by means of a "stuffing-box," the construction of which will be understood from Fig. 28. The aperture in the cylinder-cover is of larger diameter than he piston-rod, so as to avoid the friction of iron against iron A cylindrical cup or box of larger diameter is then fixed to the cylinder-covering over the opening and this is filled with plaited hemp, or some similar material, well lubricated. A cover is fitted to the upper end of the stuffing-box, which can be forced down by means of a screw, so as to compress the packing to any required extent, and in this way the effect of wear is easily obviated.

This packing must be kept sufficiently charged with oil or tallow, otherwise the steam will escape; sometimes, however, the oil is volatilised by the steam to a limited extent, and is found to injure the piston and cylinder. A self-lubricating packing has therefore been introduced, which has met with a good deal of approval; in the figure the stuffing-box is shown as packed with this.

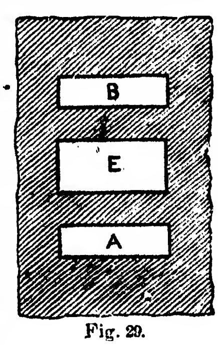


Fig. 29.

Before inquiring into the manner in which the alternate motion of the piston-rod is imparted to the machinery, we must see the way in which the supply of the steam is so regulated as alternately to enter each end of the cylinder. This may, as we have seen, be effected by means of cocks, and in the first engines made it was accomplished in this way. This plan, however, soon went out of date, and some modification of the slide-valve is now most generally adopted. In some cases spindle or "puppet" valves are employed.

The simplest form of slide-valve, and that which will best explain its action, is that known as the ordinary "three-port" slide. At one side of the cylinder is a true surface, called the "valve facing," in which there are three parallel apertures, B, E, and A (Fig. 29); of these, B and A communicate

respectively with the upper and lower ports of the cylinder, as will be seen in Fig. 30, where the same letters are employed. The centre opening, E, is the largest one, and is known as the "exhaust;" it communicates either with the condenser or the atmosphere, according as the engine is a condensing one or not. The valve, V (Fig. 30), slides over this facing, and thus allows B and A alternately to communicate with E; the other port in either case being open for the passage of steam from the boiler. Firmly secured to the valve-facing is a kind of steam-chest, C D, into which the steam-pipe, S, opens. This chest is called the valve-casing, the valve being entirely within it. In the top and bottom of it are stuffing-boxes, through which the valve-rod G passes steam-tight. This rod is firmly secured to the valve, and imparts motion to it. It is connected to some part of the engine, usually the eccentric, and is thus moved up and down so as to allow the steam to enter at the right part of the stroke, for, as will easily be seen, this is of the utmost importance. In Fig. 30 the piston is just commencing to descend, and the valve-rod is very nearly at the bottom of its stroke, so that when the piston has passed a little way down, both the ports B and A will be fully open. The steam will then pass from S by the open port B, and press on the upper surface of the piston, while the steam which filled the lower part of the cylinder during the up-stroke escapes by A into the exhaust, and thus allows the piston to descend. By the time the piston has reached the lower end, the valve-rod has been raised about twice the width of the rubbing surfaces, F F, so that now A is open to the valve-casing for the steam to enter, while the upper end of the cylinder is in communication with the exhaust by means of B and the valve.

Fig. 31.

In Cornish engines the valve-rod is very frequently moved by tappets placed on it, which are caught by studs on one of the engine-rods, and thus the valves are opened and closed almost instantaneously. When, as is more commonly the case, motion is imparted by the eccentric, the movement is much more gradual. By altering the length of the faces of the valve, the steam can be cut off at any required portion of the stroke, and thus allowed to act expansively, as it is termed. We may, for example, so arrange it that when the piston is at the middle of its stroke, the further entrance of steam is stopped, while the other end of the cylinder still remains open to the exhaust.

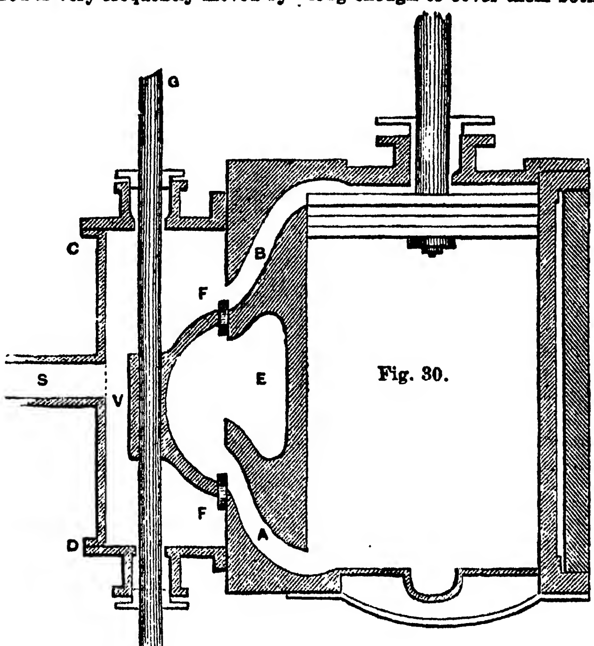


Fig. 30.

The steam contained in the upper end of the cylinder will then possess sufficient expansive force to drive the piston completely down, though of course with less power than would be the case were the steam entering all the time. At the conclusion of the stroke the steam in the cylinder will possess only half the tension it did at the moment at which the supply arrested; the second half of the descent, however, has been effected without any further expenditure of steam, and therefore all the power produced by it is so much additional advantage. There is evidently, then, a considerable gain by working the engine expansively, and in many cases the steam is cut off at a quarter, a sixth, or even an eighth of the stroke, the steam in these cases being used at a very high pressure. [illegible] alterations are very easily effected by slightly modi-; the [illegible]

Sometimes a compound slide-valve is used which is capable of adjustment, so that the steam can be cut off at any part of the stroke we desire, and in other cases the governor-balls are made to act on this expansion gear, and in this way regulate the speed of the engine by altering the period of the stroke at which the steam is cut off, instead of by moving the throttle-valve. To explain thoroughly the construction of these valves would, however, require far more space than we can spare, and is scarcely essential to a full understanding of the engine.

The valve is usually so arranged as to give what is termed a "lead;" that is, the steam-port is opened a little before the termination of the previous stroke—thus, if the piston is ascending, the upper steam-port B is opened a little way before the up-stroke is quite completed. The steam entering this serves partly as a buffer or spring, and stops the piston more gently; it also allows the lower end to communicate more rapidly with the exhaust than is otherwise the case; and if this communication be at all impeded, the steam below the piston offers a hindrance to its motion, and thus impedes the engine.

The extension of the face of the valve by which the steam is cut off is technically known as the "lap," and it is by this that the steam is cut off at any part of the stroke. In the valve we have drawn the steam would enter, until very near the completion of the stroke.

Another form of valve frequently employed is called the "long D valve," and is shown in Fig. 31. The ports here are placed at the top and bottom of the cylinder, and the valve, which in its cross section is nearly the shape of the letter D, is long enough to cover them both. The valve is packed at both ends, so as to fit steam-tight in its chamber, and has a passage, F, passing through it from end to end. Steam is admitted through the pipes to the space between the packed ends, and the pipe seen below D is the exhaust.

When in the position here shown, the steam enters the upper end of the cylinder, and forces the piston down, while the lower end is open directly to the exhaust through the port V. When the stroke is nearly completed, the valve is depressed, and the steam now enters the lower port, while that from the upper end escapes through the passage F in the middle of the valve.

In large engines, so great is the pressure of the steam on the slide-valve, that there is at times much difficulty in starting it. To obviate this, a small engine is sometimes employed; more commonly, however, a "balanced valve" is used. In this the steam is allowed to press on each of the valve, and thus the pressure and consequent friction are very greatly diminished.

Having now clearly understood the manner in which an alternate motion is imparted to the piston by the pressure of the steam, we may pass on to see how this motion is converted into one of rotation, or into any other kind of movement we may require. We must, however, remember that the essential part of the engine is that which we have already considered. In the cylinder and slide-valve there is a great resemblance in all engines, but in the remaining parts there is the utmost variety.

THE ELECTRIC TELEGRAPH.—VII.

ANOTHER FORM OF COMMUTATOR — THE DOUBLE-NEEDLE INSTRUMENT — ITS CODE — ORDINARY ALARUM — SELF-ACTING ALARUM.

THE single-needle instrument, described and figured in our last paper, is the form of the electric telegraph most generally employed, and may be seen at most telegraph stations. It is, however, rather complicated in its construction, and it would be a somewhat difficult task for an amateur to construct one on that model. There is, however, a much simpler form of instrument, which is now used in many places; one of these the intelligent student may easily make for himself, and in so doing he will acquire a much clearer insight into the principle and operation of the telegraph generally. He may even carry a wire to a friend's house, and thus be able to communicate with him.

In this instrument the transmitting portion of the apparatus, or commutator, is quite separate and distinct from the coil or receiving portion. The coil, with its needle, is sometimes mounted in a case similar to that of the instrument already described; but a simpler plan is to place the needle in the centre of a disc, and support this on a pillar and stand, after the manner shown in Fig. 29. The coil is then placed at the back of this disc, and covered, so as to protect it from the dust. The ends of the wire pass down the pillar, and are connected to the two binding-screws seen on the base of the instrument, which is placed in the circuit of the line-wire.

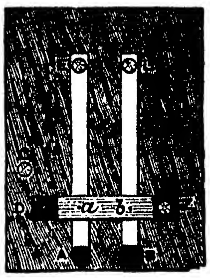


Fig. 30.

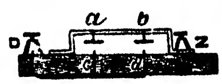


Fig. 31.

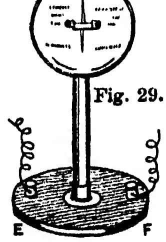


Fig. 29.

The commutator is shown in Figs. 30 and 31. A piece of mahogany or oak, about nine inches by six inches, is taken, and two strips of stout brass spring, E A and L B, are firmly fixed to it at E and L, binding-screws being fixed to each at these points. These strips are bent upwards, so that their free ends press against two studs, *a* and *b*, in the under side of a brass bridge, D Z, placed over them. The form of this will be clearly seen by the sectional view (Fig. 31).

On the extreme ends of these springs are placed finger-plates, A, B, of ivory or ebony, and by pressing on these the signals are sent. Under A and B are two stout pegs or pins of brass wire, which pass through the board, and are there connected together, and also to the binding-screw, C. The springs when at rest do not touch these pins, but remain pressing upwards against *a* and *b*.

To join up the circuit, we connect the positive and negative battery wires with C and Z respectively; E is then connected with the earth-plate, and L with one of the screws at the base of the coil—the other screw there being connected with the line-wire. Now let us, first of all, trace the course of a current which is received from the distant station. It comes along the line-wire, passes round the coil, deflecting the needle on its way, and thence to the binding-screw, L. It then travels along the strip L B to *b*, across the bridge to *a*, and along the other strip to E and the earth-plate, the circuit being thus completed through the earth-plate of the distant station.

When a message is transmitted, the current takes a different course. Suppose we desire to send an inclination to the left, we press down the left-hand spring, A, till it comes into contact with the pin, *c*. The course of the electric current will then be as follows:—From C it passes through *c* and along the strip A E to the earth-plate, returning through the coil to L, and by *b* to the binding-screw Z, which is placed on the bridge, and is connected with the zinc pole of the battery. In this way all the needles in the circuit are deflected to the left. When we desire to deflect them to the right we have only to press down B, and then, as may easily be seen, the current will pass in the reverse direction, viz., from L to E, instead of from E to L, and all the needles will accordingly move to the right.

It will thus be seen that in this instrument all we have to do is to depress the right or the left spring, according as we wish to deflect the needle to the right or to the left. This can be done rather more rapidly than the handle in the other instrument can be moved, and this commutator, therefore, has an advantage over that in point of speed. It is, however, less certain in its action, as the points of the pins are apt to become somewhat corroded or covered with dust, and the current will, of course, be interrupted by this. Both hands are commonly employed in working it, but care must be taken not to keep either spring out of contact with the stud above it while the other spring is being pressed down, as this will break the circuit.

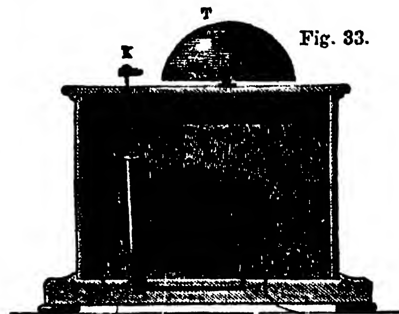
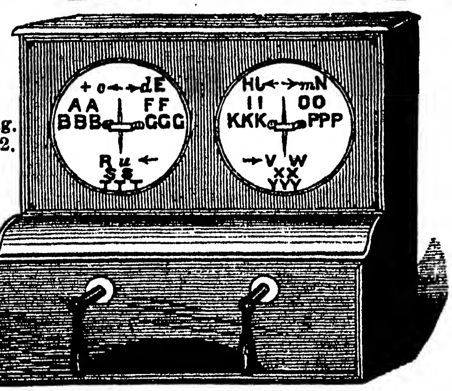


Fig. 33.

Sometimes, instead of the finger-plates, two studs or buttons are used, but the action is the same in either case.

There are two main drawbacks to the use of the single-needle instrument: one is, that there is no record left of the signs, and if the eye be not very quick, or if the attention be called off, one or more of them may very easily be missed. This is, however, to a considerable extent obviated by practice. Another drawback to its use is that it is somewhat slow. To meet this difficulty the double-needle instrument (Fig. 32) was introduced, and is nearly the most rapid instrument in use. It is frequently employed on lines where there is much communication, and where speed is an important object; the great hindrance, however, to its general employment is the fact of its requiring two line-wires and two sets of batteries. It is, in fact, merely two single-needle instruments arranged side by side in the same case; each of these has a commutator and coil made on the plan already described.

Fig. 32.



The advantage of this instrument is that fewer signs are required than with a single needle.

In the latter case, only two signs can be sent with a single movement; in this, six can be so sent, since we can use either dial by itself or both simultaneously, and in either case can give an inclination either to the right or the left. No letter, therefore, requires more than three signs, and most can be sent with two. The code employed with this instrument is very simple, and is indicated by the letters on the dial-plates. Omitting Q, Z, and J, we have twenty-four letters left, reckoning + as one. The first eight of these are sent with the left-hand dial alone, the next eight with the right-hand one, and the remainder with both, used simultaneously. J is dispensed with altogether, as I takes its place; Q is represented by the needles pointing in reverse directions, the upper ends being together, thus /\; and Z is denoted by the lower ends of the

needles inclining towards each other, thus V. For the rest of the alphabet we must refer to the dials. Taking the left-hand one first, zero or + is placed once to the left of the needle, showing that this is denoted by a single beat in that direction; similarly, A is denoted by two and B by three beats in the same direction. This is shown by the number of times they occur on the disc. E, F, and G are denoted respectively by one, two, or three inclinations to the right. C is put in different type, and has an arrow pointing to it, to indicate that it requires alternate movements of the needle, first to the left, on which side it is placed, and then to the right. D likewise requires alternate beats, one to the right being followed by one to the left. The letters from H to P are represented by precisely similar movements of the right-hand needle.

The other letters, which require both needles, are marked on the lower parts of the dials. R, S, and T require one, two, and three beats respectively to the left; U is denoted by alternate beats, first to the left and then to the right; W, X, Y, and V require similar movements in reverse directions.

We may render this more clear by putting all the signs in a tabular form, thus:—

\	\\	\\\	\/	/\	/	//	///	
+	A	B	C	D	E	F	G	Left dial.
H	I	K	L	M	N	O	P	Right dial.
R	S	T	U	V	W	X	Y	Both dials.

Both hands are employed in working this instrument, and it requires more care and attention to read it; when this is attained, messages may be sent with a speed of from forty to sixty words a minute. But, as we have already stated, two line-wires and batteries are required, and these entail so much extra cost, both in construction and maintenance, that the instrument is not nearly as much used as it otherwise would be.

We have now explained the construction of two parts of our telegraph instrument, viz., the receiving and the transmitting arrangements. There is, however, another very important part to which we must refer: some means of calling the attention of the receiving clerk to the fact that a message is coming is required. He cannot be expected to keep his eye constantly on the dial-plate of the instrument, and though the click of the needle against its studs is often distinctly audible, yet this may not be noticed: an alarum is therefore an essential thing, and many different kinds have been tried.

A bell is nearly always employed for this purpose. Sometimes it is rung by the electric current itself; in other cases it is driven by clockwork, and all that the current does is to liberate a detent, and allow the clockwork to act. This is the simplest and, in many cases, the best form. A spring sets in motion a train of wheels, and thus strikes the bell. A small catch, however, engages a tooth or a stud in one of the wheels. This catch is affixed to a lever, which is so arranged that when the current passes round an electro-magnet suitably placed, the lever is moved and the mechanism set free. The alarum, therefore, continues to ring as long as the current passes and the spring is kept wound up. This kind of alarum is simple, and not likely to get out of order. Sometimes a tell-tale is affixed to it, so that, as soon as it rings, a disc is moved and indicates the fact of the bell having been rung. One great advantage of this is, that if the clerk has been away for a short time, he will on his return at once know whether his bell has rung during his absence.

Often, however, the clockwork is altogether dispensed with, the bell being rung by the electric current alone. The hammer, in this case, is mounted upon a piece of spring or wire, attached to the middle of which is a piece of iron, which serves as the keeper to an electro-magnet placed near it. This is so arranged that when the keeper is close to the magnet the hammer *almost* touches the bell; the jerk, when it is attracted, is then sufficient to strike the bell loudly without damping the sound by allowing the hammer to remain in contact with it. By this plan only one stroke of the bell is given for each current sent.

A much better plan, and one more generally adopted, is to arrange the bell so that it continues to ring as long as the current is passing. The manner in which this is accomplished will easily be learnt by reference to Fig. 33, which shows the interior of one of these self-acting alarums. The bell, T, is placed on the outside of the case, the hammer, K, being supported on a piece of spring, *m*, so that it oscillates very freely. An electro-magnet, *e*, is placed inside the case, and its keeper, *c*, is attached to the rod of the hammer. Behind *c* is a spring, *g*, in contact with it, but so arranged that when the keeper is drawn against the poles of the magnet the contact shall cease. Not unfrequently a screw tipped with platinum is substituted for this spring.

The ends of the wire which passes round the electro-magnet are connected with the screws marked *p p;* and, as will be seen, the current, after passing round the coils of the magnet, has to pass along *m* and through *g*, so as to complete the circuit. When the instrument is at rest, *c* and *g* are in contact, and, accordingly, as soon as a current is transmitted, it makes *e* into a magnet, and draws the keeper home to it, thereby striking the bell. In doing so, however, contact is broken between *c* and *g*, and the circuit being interrupted, the keeper is drawn back to its place by the spring on which it is supported. This renews the contact, and again converts *e* into a magnet, so that the keeper is again attracted, and another stroke is given to the bell. This process continues as long as the current passes, so that the distant operator, by merely keeping his key pressed down or his handle deflected, produces a continuous ringing, and thus soon draws the attention of the station to which he wants to speak.

When several stations are in the circuit, the bell at each rings: the clerk then mentions the one to whom he wants to speak, and as soon as that one acknowledges, he sends the message. The other clerks can, if necessary, short circuit their own instruments, so as to cause less obstruction to the passage of the current.

ELECTRICAL ENGINEERING.—XV.

BY EDWARD A. O'KEEFFE, B.E., A.S.T.E.,

Demonstrator in Electrical Engineering, City and Guilds of London Technical College, Finsbury.

MEASURING INSTRUMENTS (*continued*).

THE Siemens electro-dynamometer possesses as essential features some of the best, and, at the same time, some of the worst qualities which can belong to any commercial measuring instrument. It possesses the advantage that a single observation is sufficient to calibrate it, though a number of them should always be made, and the mean value taken as the *constant of the instrument.* It possesses no permanent magnets; it can be used for measuring continuous currents to a considerable degree of accuracy, and in the case of alternating currents it can be relied on to give accurate results when there is little self-induction in the circuit, as in the case of an ordinary electric light installation; but when the self-induction is considerable in the circuit, as in the case of an electric light installation in which transformers are used, the readings on the Siemens electro-dynamometer may give results far below the true strength of the currents used. Indeed, no ampère meter at present in the market will measure accurately the strength of an alternating current in a circuit containing much self-induction.

Against these advantages the following defects must be placed:—It is not portable, owing to the movable coil being suspended by a thin thread (this suspension can, however, be lowered when the instrument is being moved), and the electric connection with this coil being made with mercury cups; it is not dead-beat, it is not direct-reading, and when the pointer has been brought to zero, the square root of the deflection must be extracted, and the result multiplied by the constant of the instrument in order to obtain the current's strength; moreover, this adjustment of the pointer takes some time, which may be extremely awkward in the case of an unsteady current; it cannot be used near dynamos as its indications are seriously influenced by the presence of strong magnets in its vicinity.

Notwithstanding all these disadvantages it is an exceedingly useful instrument when properly used. Its proper place is the laboratory where it can be permanently set up, calibrated, and used as a standard instrument, rather than in the dynamo room where it is liable to be influenced by the presence of the powerful electro-magnets, or damaged by rough usage. As its controlling force is a spiral spring its constant remains unchanged for years, unlike those ampère-meters in which the controlling force is a permanent magnet.

AYRTON AND PERRY'S HORSE-SHOE AMPÈRE-METER.

In 1881 Professors Ayrton and Perry brought out their horse-shoe type of ampère-meter, which supplied a want then much felt for a portable and direct-reading instrument. The interior of this instrument is shown in Fig. 32.

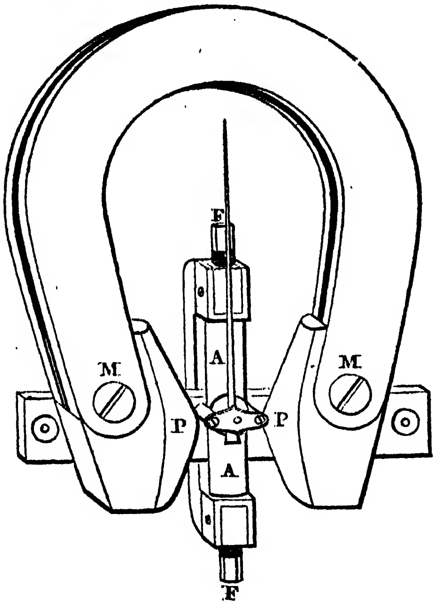


Fig. 32.—AYRTON AND PERRY'S HORSE-SHOE AMPÈRE-METER.

The controlling force is supplied by a very powerful horse-shoe magnet, M M, having two curved soft-iron pole-pieces, P P, between which is delicately pivoted a small thick magnetic needle not shown in the figure, but which has attached to it at right angles to its axis a light aluminium pointer, which serves the double purpose of magnifying the small motion of the magnet, and indicating the strength of current which produces that motion. The wire which carries the current is wound on the brass bobbin, A A, which is divided into two parts between which the needle is situated. Two soft iron cores, F F, are screwed into the bobbin, one at each end, and these cores are capable of being screwed more or less into the bobbin as may be required. The object of this arrangement of cores and pole-pieces is to have the motion of the magnet due to the passage of the current in the coil directly proportional to the strength of that current, or, in other words, to have the instrument direct-reading. Neglecting for the present the effect of the cores, F F, on the needle: when no current is passing, the needle is kept in position under the influence of the two powerful pole-pieces, P P; when a current passes, the needle is deflected through a certain angle; if the current's strength is doubled it will be found that the needle will not move through double the previous angle, and as the current is still further increased the deflection of the magnet will not increase in proportion. This want of proportionality of the deflection with the increase of current is rectified by means of the two soft iron cores, F F. As the magnet deflects it comes under the action of these cores which tend further to increase the deflection. If they are screwed too far into the bobbin they assist the coil too much, and the deflection of the magnet will be too great compared with the current which produces it; on the other hand, if they are not screwed in enough the deflection will be too small as compared with the current which produces it. Between these two positions there is a certain intermediate range in which the cores may be moved which gives deflections of the magnet practically proportional to the currents which produce them, and within that range the cores can be moved in or out so as to alter the sensibility of the instrument without altering the proportionality between the current and the deflection which it produces. The light aluminium pointer attached to the magnet moves over a graduated scale on which the divisions are at equal distances apart, and each division corresponds to one ampère, the final adjustment of the instrument being made by screwing in or out the cores, F F, according as the indication for a given current is too low or too high. The scale is usually graduated up to fifty degrees at each side of zero, and the instrument will then by a special arrangement of the coils and commutator measure any current between ·1 and 50 ampères.

The arrangement of the coils is peculiar and forms an essential feature of this ampère-meter. Instead of being wound with one wire, as is the case in most instruments, it is wound with ten wires of exactly the same resistance having the appearance shown in Fig. 33.

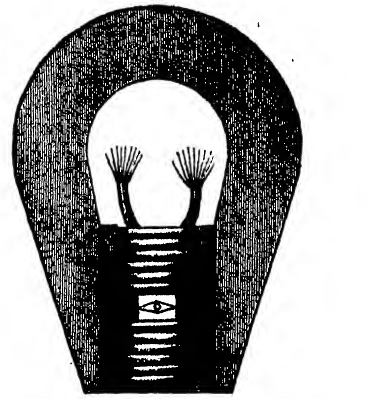


Fig. 33.—AYRTON AND PERRY'S AMPÈRE-METER.

The ends of these coils are brought up to a commutator by means of which they can be placed all in series, or all in parallel, thus giving two degrees of sensibility for which the instrument may be used. When they are all in series, currents from ·1 to 5 ampères can be measured, when they are all in parallel currents from 1 to 50 can be measured, thus making the instrument suitable for measuring the current flowing through an arc or an incandescent lamp.

Though this type of commutator is peculiar to this instrument, it might with equal advantage be used in any of the measuring instruments which contain permanent magnets and a coil. Besides extending the range of the ampère-meter, it also allows it to be calibrated either by a strong or weak current.

PRINCIPLES OF DESIGN.—XI.

ART FURNITURE (*continued*).

By Christopher Dresser, Ph.D., F.L.S.

I fear that I have very feebly enforced and very inefficiently illustrated the true principles on which works of furniture should be constructed; and yet I feel that the structure of such works is of importance beyond all other considerations. Space is limited, however, and I must pass on; hence I must hope that I have induced the reader to think for himself, and if I have done so I shall have fulfilled my desire, for his progress will then be sure.

Respecting structure, I have but a few general remarks further to make, and all these are fairly embraced in the one expression, "be truthful." An obvious and true structure is always pleasant. Let, then, the "tenon" and the "mortise" pass through the various members, and let the parts be "pinned" together by obvious wooden pins. Thus, if the frame of a chair-seat is tenoned into the legs, let the tenon pass through the leg and be visible on the outer side, and let it be held in its place by glue and wooden pins—the pins being visible. In this way that old furniture was made which has endured while piece after piece of modern furniture, made with invisible joints and concealed nails and screws, has perished. This is a true structural treatment, and is honest in expression also.

I do not give this as a principle applicable to one class of

furniture only, but to all. When we have "pinned" furniture with an open structure (see the back of Gillow's chair, Fig. 27), the mode of putting together must be manifest; but in all other cases the tenons should also go through, and the pins by which they are held in their place be driven from one surface to the other side right through the member.

In my first lesson on furniture (see page 311) I said that after the most convenient form has been chosen for an object, and after it has been arranged that the material of which it is to be formed shall be worked in the most natural or befitting way, then the block-form must be looked to, after which comes the division of the mass into primary parts, and lastly, the consideration of detail.

As to the block-form, let it be simple, and have the appearance of appropriateness and consistency. Its character must be regulated, to an extent, by the nature of the house for which the furniture is intended, and by the character of the room in which it is to be placed. All I can say to the student on this part of the subject is this: Carefully consider good works of furniture whenever opportunity occurs, and note their general conformation. A fine work will never have strong architectural qualities—that is, it will not look like part of a building formed of wood instead of stone. There is but small danger of committing any great error in the block-form, if it be kept simple, and look like a work in wood, provided that the proportions of height to width and of width and height to thickness are duly cared for.

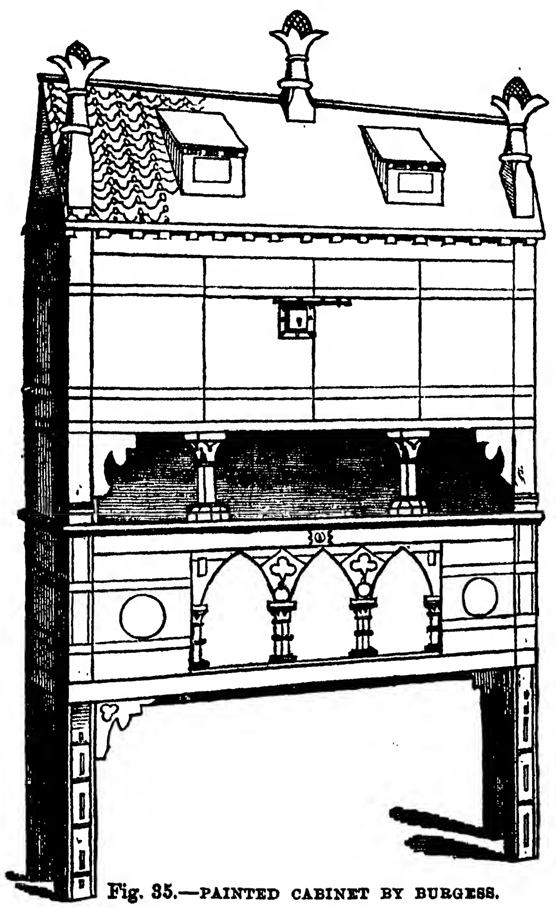


Fig. 35.—PAINTED CABINET BY BURGESS.

After the general form has been considered, the mass may be broken up into primary and secondary parts. Thus, if we have to construct a cabinet, the upper part of which consists of a cupboard, and the lower portion of drawers, we should have to determine the proportion which the one part should bear to the other. This is an invariable rule—that the work must not consist of equal parts; thus, if the whole cabinet be six feet in height, the cupboards could not be three feet while the drawers occupied three feet also. The division would have to be of a subtle character—of a character which could not be readily detected. Thus the cupboard might be 3 feet 5 inches, and the drawers collectively 2 feet 7 inches. If the drawers are not to be all of the same depth, then the relation of one drawer, as regards its size, to that of another must be considered, and of each to the cupboard above. In like manner the proportion of the panels of the doors to the styles must be thought out; and until all this has been done no work should ever be constructed.

Next comes the enrichment of parts. Carving should be very sparingly used, and is best confined to mouldings, or projecting or terminal ends. If employed in mouldings, those members should be enriched which are more or less completely guarded from dust and injury by some overhanging member. If more carving is used, it should certainly be a mere enrichment of necessary structure—as we see on the legs and other uprights of Mr. Crace's beautiful sideboard, by Pugin (Fig. 34). I am not fond of carved panels, but should these be employed the carving should never project beyond the styles surrounding them, and in all cases of carving no pointed members must protrude so as to injure the person or destroy the dress of those who use the piece of furniture. If carving is used sparingly, it gives us the impression that it is valuable; if it is lavishly employed, it appears to be comparatively worthless. The aim of art is the production of repose. A large work of furniture which is carved all over cannot produce the necessary sense of repose, and is therefore objectionable.

There may be an excess of finish in works of carving connected with cabinet work; for if the finish is too delicate there is a lack of effect in the work. A work of furniture is not a miniature work, which is to be investigated in every detail. It is an object of utility, which is to appear beautiful in a room, and is not to command undivided attention; it is a work which is to combine with other works in rendering an apartment beautiful. The South Kensington Museum purchased in the 1867 Paris International Exhibition, at great cost, a cabinet from Fourdonois; but it is a very unsatisfactory work, as it is too delicate, too tender, and too fine for a work of utility and furniture—it is an example of what should be avoided rather than of what should be followed. The delicately-carved and beautiful panels of the doors, if cut in marble and employed as mere works of sculpture, would have been worthy of the highest commendation; but works of this kind wrought in a material that has a "grain," however little the grain may show, are absurd. Besides, the subjects are of too pictorial a character for "applied works"—that is, they are treated in too pictorial or naturalistic a manner. A broad, simple, idealised treatment of the figure is that which is alone legitimate in cabinet work.

Supports or columns carved into the form of human figures are always objectionable.

Besides carving, as a means of enrichment, we have inlaying, painting, and the applying of plaques of stone or earthenware, and of brass or ormolu enrichments, and we have the inserting of brass into the material when buhl-work is formed.

Inlaying is a very natural and beautiful means of enriching works of furniture, for it leaves the flatness of the surface undisturbed. A great deal may be done in this way by the employment of very simple means. A mere row of circular dots of black wood inlaid in oak will often give a very good effect; and the dots can be "worked" with the utmost ease. Three dots form a trefoil, four dots a quatrefoil, six dots a hexafoil, and so on, and very desirable effects can often be produced by such simple inlays.

Panels of cabinets may be painted, and enriched with ornament or flatly-treated figure subjects. This is a beautiful mode of enrichment very much neglected. The couch (Fig. 30) I intended for enrichment of this kind. If this form of enrichment is employed, care should be exercised in order that the painted work be in all cases so situated that it cannot be rubbed. It should fill sunk panels and hollows, and never appear on advancing members.

I am not fond of the application of plaques of stone or of earthenware to works of furniture. Anything that is brittle is not suitable as an enrichment of wood-work, unless it can be so placed as to be out of danger.

Ormolu ornaments, when applied to cabinets and other works

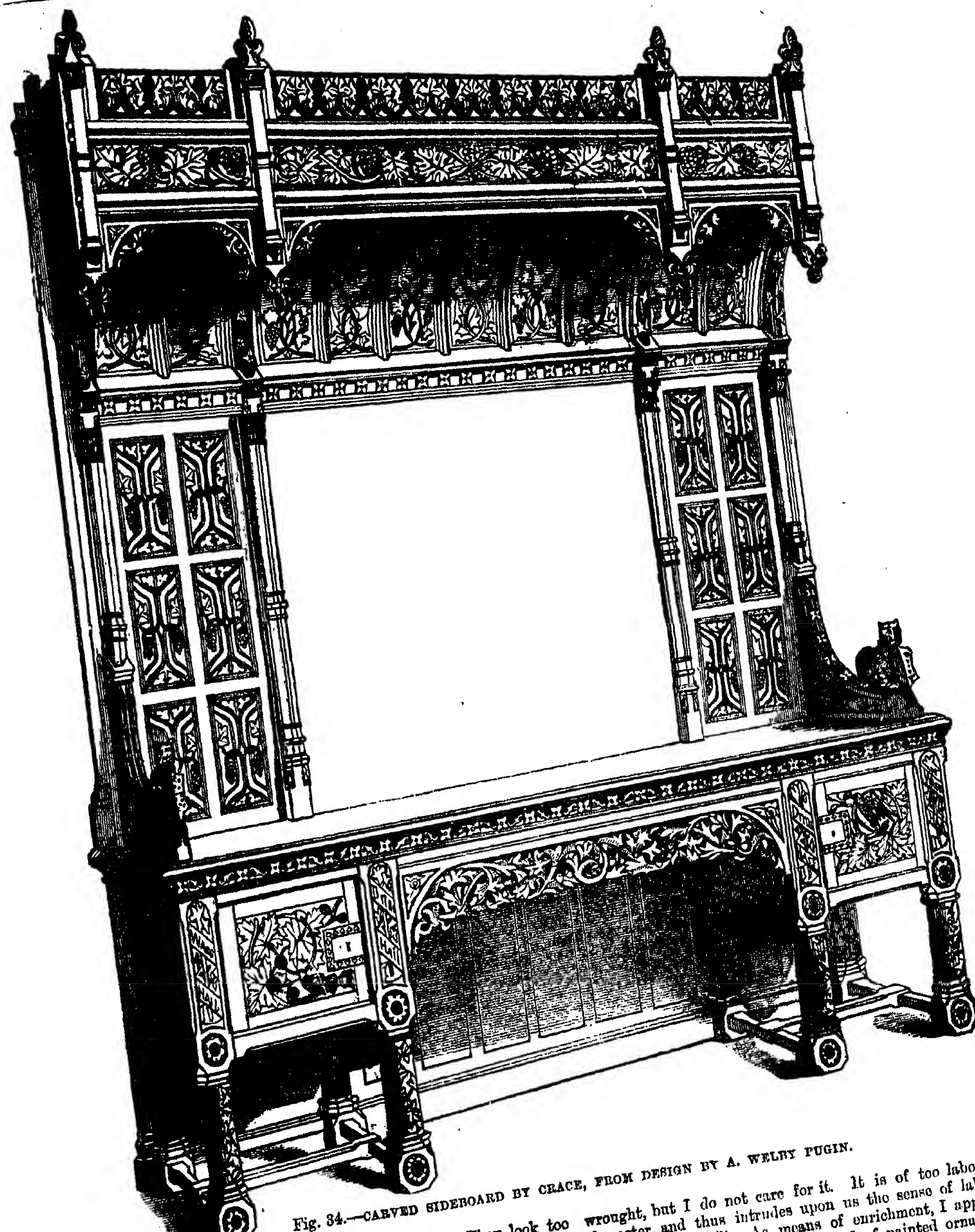


Fig. 34.—CARVED SIDEBOARD BY CRACE, FROM DESIGN BY A. WELBY PUGIN.

of furniture, are also never very satisfactory. They look too separate from the wood of which the work is formed—too obviously applied; and whatever is obviously *applied* to the work, and is not a portion of its general fabric, whether a mass of flowers carved in wood, or an ormolu ornament, is not pleasant.

Buhl-work is often very clever in character and skilfully wrought, but I do not care for it. It is of too laborious a character, and thus intrudes upon us the sense of labour as well as that of skill. As means of enrichment, I approve of carving, sparingly used, of inlays, and of painted ornament in certain cases; and the just employment of these means is capable of securing the utmost beauty in cabinet-work. Ivory inlaid with ebony is very beautiful.

In conjunction with this article, we engrave a sideboard executed by Mr. Crace, from the design of Mr. A. Welby Pugin, to which I have before alluded (Fig. 34), and a painted cabinet by the late Mr. Burgess (Fig. 35), whose abilities as a Gothic architect were of the highest order. Both of these works are worthy of study of a very careful kind.

In the sideboard, notice first the general structure or construction of the work, then the manner in which it is broken up into parts, and lastly, that it is the structural members which are carved. If this work has faults, they are these: first, the carving is slightly in excess—thus, the panels would have been better plain; and, second, in some parts there is a slight indication of a stone structure, as in the buttress character of the ends of the sideboard.

To the cabinet much more serious objections may be taken.

1. A roof is a means whereby the weather is kept out of a dwelling, and tiles afford a means whereby small pieces of material enable us to form a perfect covering to our houses of a weather-proof character. It is very absurd, then, to treat the roof of a cabinet, which is to stand in a room, as if it were an entire house, or were to stand in a garden.

2. The windows in the roof, which in the case of a house let in light to those rooms which are placed in this part of the building, and are formed in a particular manner so as the more perfectly to exclude rain, become very absurd when placed in the roof of a cabinet. These, together with the imitation tiled roof, degrade the work to a mere doll's-house in appearance.

3. A panelled structure, which is the strongest and best structure, is ignored; hence strong metal bindings are necessary.

The painting of the work is highly interesting, and had it been more flatly treated, would then have been truthful, and would yet have lent the same interest to the cabinet that it does now, even if we consider the matter from a purely pictorial point of view.

VEGETABLE COMMERCIAL PRODUCTS.

XIV.

DYE PLANTS (*continued*).

INDIGO (*Indigofera tinctoria*, L.; natural order, *Leguminosæ*).—A shrub from two to three feet high, with pinnate leaves, and racemes of greenish-coloured flowers, marked with vermilion red. Indigo is also extracted from two other species, viz., *Indigofera anil* and *I. cœrulea*.

This plant is a native of India, whence our chief supplies are received. It is principally grown in Bengal, from 20° to 30° N. latitude. Indigo is also cultivated in Java, the Philippine Islands, Egypt, the West Indies, and British Honduras.

The best time for cutting the plant is when it begins to flower, because then it is always richest in its peculiar secretions. The plants, when cut, are first laid in a vat, called the steeper, about twelve or fourteen feet long and four feet deep, and filled with water. In twelve or sixteen hours the water begins to ferment, swell, and grow warm; the highest point of its ascent is marked, for when it ceases to swell fermentation begins to abate. The manager now opens a tap to let off the water into a second vat, called the beater, and the gross sediment at the bottom of the first one is carried off and used as manure for the next crop of plants, for which purpose it is excellent. The indigo fluid received into the second vat is kept actively stirred and beaten with bamboos until it begins to granulate. When granulated sufficiently, the liquor assumes a deep purple colour, the whole being troubled and muddy. It is now allowed to settle, and as the upper part of the water clears, it is removed into other vessels, until nothing remains but a thick sediment at the bottom of the vat. This is put into gunny bags, which are hung up to dry. To finish the drying, the indigo is turned out of the bags, exposed to the sun, worked upon boards with a spatula, and put into boxes, and again exposed to the sun until fully dried, when it is ready for market.

The indigo plant grows best in the East Indies. It was first brought to Europe by the Dutch in the middle of the seventeenth century. It is now imported, every year in increasing quantities, from the East Indies, and also from both North and South America, to which it has been transplanted. Indigo is used in the dyeing-houses of our woollen, linen, cotton, and silk manufacturers, and has almost completely displaced the native woad (*Isatis tinctoria*, L.) formerly used. The finest sort comes from Bengal *viâ* Calcutta. British India has almost a monopoly of the indigo trade, in which all the Presidencies have a share. The French import a very good quality from the Isle of Bourbon, and the Dutch from the Sunda Islands, in the East Indies. The best American indigo is raised in Guatemala, in Central America, and an inferior kind at Caracas, in Brazil, St. Domingo, Carolina, and Louisiana. There are extensive indigo plantations on the fertile delta of the Nile, under the management of Hindoos. Indigo has also been received recently in small quantities from Madeira, the river Senegal, and Sierra Leone.

Good indigo is known by the purity of its colour and its lightness, which is indicative of the absence of any earthy impurity. A blue carmine, made out of this substance, is a very high-priced colour, used by painters. The quantity of indigo imported in 1886 into the United Kingdom was 85,308 cwt.

TURMERIC (*Curcuma longa*, L.; natural order, *Zingiberaceæ*).—This is a stemless plant, with palmated tuberous roots of a deep orange colour internally, long-stalked, lanceolate, smooth leaves, and flowers in a central oblong green spike.

Turmeric is a native of the warm parts of Asia, and is found in India, China, Cochin-China, Java, and Malacca, where it is extensively cultivated for the sake of the beautiful yellow dye afforded by its root, and also as a condiment, as it forms a principal ingredient in Indian curry-powder. Turmeric gives a beautiful but fugitive gold colour to silks. Paper stained with turmeric is much used by chemists as a test for alkalies, which colour turmeric paper reddish or brownish. Turmeric is also used in making Dutch pink and gold-coloured varnish. There are several varieties of this dye in the market, the principal of which are the Long Turmeric (*Curcuma longa*, L.), and the Round, better known as Chinese turmeric. It need hardly be added that the chief imports of turmeric into the United Kingdom come from China and India.

QUERCITRON (*Quercus tinctoria*, Michx.; natural order, *Cupuliferæ*).—This oak grows from sixty to ninety feet high. Its leaves are six to eight inches long, obovate, deeply sinuate-lobed, pubescent beneath; the acorn small ovoid, seated in a sub-sessile cup, which tapers at the base.

This tree is indigenous to the United States, growing abundantly in Pennsylvania, North and South Carolina, and Georgia. The inner bark is an article of commerce under the name of quercitron, and furnishes a yellow dye, which has now nearly superseded the use of our indigenous weld (*Reseda luteola*, L.) in calico printing. Quercitron, when crushed, resembles a mass of short yellowish-white fibres, mixed with powdery particles, and in this state is sent over in casks. From 3,000 to 4,000 tons are annually received in England from New York, Philadelphia, and Baltimore.

YELLOW BERRIES (*Rhamnus infectorius*, L.; natural order, *Rhamnaceæ*).—This plant is a species of buckthorn, and is a native of Persia, Turkey, and the south of Europe. It is a procumbent shrub, growing naturally in rough, rocky places. The unripe berries furnish a yellow dye, which is largely employed in calico printing, for dyeing morocco leather and paper, as well as for the preparation of sap green and Dutch pink. The largest and best yellow berries are the Persian, which come to this country *viâ* Aleppo and Smyrna; a considerable quantity is also received from France and Turkey. The importation amounts annually to between 500 and 600 tons.

FUSTIC (*Maclura tinctoria*, Nutt; natural order, *Urticaceæ*).—A large and handsome evergreen tree, growing in the West Indies and tropical America. There are large forests of this tree in the Antilles, especially in Jamaica, Cuba, Porto Rico, and Tobago. Fustic is brought to market in long pieces or logs. The beautiful yellow and red veined is considered to be the best. Fustic dyes yellow, olive, brown, maroon, bronze, and Saxon green.

WOAD (*Isatis tinctoria*; natural order, *Cruciferæ*).—Woad is much cultivated in France, Normandy, Alsace, and also in Germany, where it was in use a thousand years ago. It is indigenous to England and Germany. The blue matter of this plant is contained in its leaves. Woad was used by the ancient Britons to stain their bodies. The extensive use of East Indian indigo has greatly restricted the cultivation of woad; but as the dyers very unwillingly dispense with it, on account of its cheapness and the durability of its colour, it is probable that indigo will never entirely supersede its use.

NICARAGUA or PEACH WOOD (*Cæsalpinia echinata;* natural order, *Leguminosæ*).—This dye-wood gets its name from the republic of Nicaragua, in Central America. It reaches this country in blocks about four feet in length and eight inches in diameter. It dyes a delicate peach and cherry colour, and is much used. That which comes from Peru yields the finest shades of colour.

Several other species of *Cæsalpinia* yield dye-woods. Thus *Cæsalpinia crista* furnishes the Brazil wood, and *Cæsalpinia brasiliensis* the Brazilletto wood, which yields some very fine rose-coloured, yellow, and orange-red dyes, according to the mordants used. About 800 tons of the first and 400 tons of the latter annually arrive in England from the vast forests of South America, which are very rich in dye-woods. Brazil wood is imported principally from Pernambuco, and is also known by the name of Fernambuk wood, in allusion to the place of importation. Besides its usefulness as a dye-wood, it also serves for objects of art; bows of violins are especially made from Fernambuk wood.

SAPAN WOOD or BUKKUM WOOD (*Cæsalpinia sapan*) furnishes another good red dye, which is very considerably employed in many countries both in India and in Europe.

RED SANDERS WOOD (*Pterocarpus santalinus*, L.; natural order, *Leguminosæ*) yields a dye of a bright garnet-red colour, and is chiefly employed for dyeing wood. The tree which produces the wood is a lofty one, common about Madras and other parts of India. The exports of this wood from Madras in one year only have been nearly 2,000 tons. We import also usually between 700 and 800 tons a year from Calcutta and Bombay.

COLOUR.—VIII.

By PROFESSOR A. H. CHURCH, M.A., Royal Academy.

APPLICATIONS OF PRINCIPLES OF TRIPLE DISTRIBUTION, BALANCE, AND QUALITY IN ESTIMATING THE AGREEABLENESS OF CERTAIN ASSORTMENTS OF COLOUR.

WE may now proceed to illustrate by a few examples the application of the principles of the distribution, balance, and quality of colours to the triple assortments named in the last lesson, which were of three series.

SERIES I.—*Assortments of two primary colours* with white, grey, or black constitute the first series. They are generally preferable to assortments in which one primary and one secondary colour occur, unless these happen to be complementary, when the effect is more agreeable still. The more brilliant colour must be used in moderation, and may be distributed in narrow lines or delicate forms. The deeper colour usually requires a broader treatment, and to be present in larger quantity. In separating the two bright primaries, yellow and red, from each other, black is preferable to white; while in separating blue and red, white is preferable to black. In such instances we have to pay attention to the balance of tone, and must not allow the bright or the deep elements of colour to preponderate. Grey is very often of use in colour assortments, where white or black might produce too marked a contrast.

SERIES II.—*Assortments of one primary and one secondary colour* with white, grey, or black. It is needless to say that in the cases belonging to Series II. the effect of a primary with its complementary secondary is far superior to all the other combinations. Thus yellow and violet constitute a more agreeable assortment than yellow and orange. But yellow and violet cannot be much improved by the introduction of black, which too much resembles the violet, and differs too much from the yellow; while white is liable to objection precisely the converse of this. Nor does grey produce a very satisfactory effect in this arrangement. The more agreeable the combination of two colours when in contiguity the less improvement do they require, and the less do they experience from the introduction of white, grey, or black. Such assortments as that of yellow and orange are, on the other hand, greatly improved by the introduction of another element to define or emphasise them. The arrangement yellow, black, and orange is vastly superior to that with yellow and orange alone. When white is used in an assortment of this nature containing two bright colours, it often produces a happier effect when introduced so as not to the colours, but to precede the brighter of them—thus, white, yellow, orange. If white be also inserted between the yellow and the orange, the effect is impoverished. When two deep colours are used together, and in combination with black, the black may advantageously follow the deeper colour, but such an assortment as violet, blue, and black is a sombre one; yet to many eyes it will appear more satisfactory than one in which alternate spaces of white are introduced, in order to restore the balance of tone.

SERIES III.—*Assortments of Two Secondary Colours.*—Orange and green may be advantageously separated by black, orange and violet by grey, and violet and green by white.

We hope the examples just given will be sufficient to enable our readers, with the aid of actual experimental trials, to judge of the merit of any triple assortment of colour, and to arrange many agreeable combinations suitable for special purposes. We may just allude here to one of the applications flowing out of the principles which we have been enunciating. It is an application of great service to ornamental designers, and has been extensively carried out into practice. It may be briefly stated in three rules or propositions:—1. If in an ornamental design the ground be of a deep tone of colour, and the forms or figures upon it be of a less intense or lighter complementary colour, then these forms should be outlined with white, or with a light tone of grey, or, in any event, with some colour of a tone lighter either than the ground or the pattern. 2. If in an ornamental design the ground be of a light tone of colour, and the forms or figures upon it be of a more intense or deeper complementary colour, then those forms should be outlined with black, or with a deep tone of grey, or, in any event, with some colour of a tone deeper than either the ground or pattern. 3. In painting with tones of one colour, or monochrome, the same rule must be observed, varying the depth or tone of the outline according to the relations as to tone of the pattern and the ground, as in the preceding rules.

TECHNICAL DRAWING.—XXVI.

MECHANICAL DRAWING (*continued*).

CAMS.

CAMS are variously-formed plates, or grooves, by means of which a circular may be converted into a reciprocating motion.

The circular motion being uniform, the reciprocating motion may also move uniformly as a sliding-bar; or its velocity may be varied at pleasure.

The Heart-shaped Cam.—The form of this cam is delineated by means of a double Archimedes' spiral, the construction of which is given in Fig. 247.

Let 12 XII be the widest limit of the required spiral.

Describe a circle with 12 XII as a radius.

Divide this circle into any number of equal parts as I to XII, and draw radii.

Divide one of the radii into a corresponding number of equal parts, as 1 to 12.

From the centre, with radius A 1, describe an arc cutting the radius I in B.

From the centre continue describing arcs, with radius 2, 3, etc., cutting the radii II, III, etc., in C, D, E, etc.

From 12 trace a curve passing through these points, which will be the spiral required.

Fig. 248 is an example of the *heart-shaped cam*.

Let a a' be the rectilinear distance to be traversed, and O the centre of the shaft, on which the cam is fixed.

It is required to make the point a advance to a' in a uniform manner, during a semi-revolution of the shaft, and to return it to its original position in the same manner during a second semi-revolution.

From the centre O, with the radii O a and O a', describe circles; divide the outer one into any number of equal parts; divide the line a a' into the same number of parts.

From O, with radius O 1, O 2, O 3, etc., describe circles cutting the radii correspondingly numbered, and thus the points A, B, C, D, etc., will be obtained. The curve drawn through these points will be the spiral form for the cam required to raise the point a to a'.

But it is not possible to employ a mathematical *point* in practice, since "a point is that which has position but not magnitude." Therefore, an anti-friction roller, which has its centre where the point would be, is employed, and in consequence of

this, the size of the cam has to be reduced from that of the original curve to allow for the size of the roller.

To accomplish this, with the radius of the anti-friction roller describe arcs from A B, C D, etc., and draw the curve which is to form the outline of the cam to touch the highest point of these arcs. Observe that the highest point would not be on the radii; for example, it would not be at *g*, but on a line perpendicular to the curve at G—viz., at *h*.

This form of cam is symmetrical to the line *a* which passes through its centre—in other words, the first half which pushes the roller, and consequently the rod A′, to the end of which the roller is fitted, from *a* to *a*′, is precisely the same as the second half, with which the roller keeps in contact during the descent of the roller from A′ to *a*. Thus a regular alternating motion is given to the roller by the circular motion of the cam.

Cams of small size are simply flat discs of the shape required. When large, they are formed with a crown or rim, B′, of equal thickness all round; a boss, C (by means of which it is keyed on to the shaft D), and arms, E, F, G. These are strengthened internally by a feather or web, G G.

The line of this web is, in the first place, parallel to the rim, curves into the part strengthening the arms, becomes wider as it nears the boss, and is then united to the adjoining web by an arc—as at I′—or returns into the outer portion by an arc—as at J′.

It may here be remarked that the centres, from which these uniting arcs are struck, are shown on the one side. The inner curve of the rim and that of the web are obtained in the same manner as the external form of the cam was deduced from the original spiral.

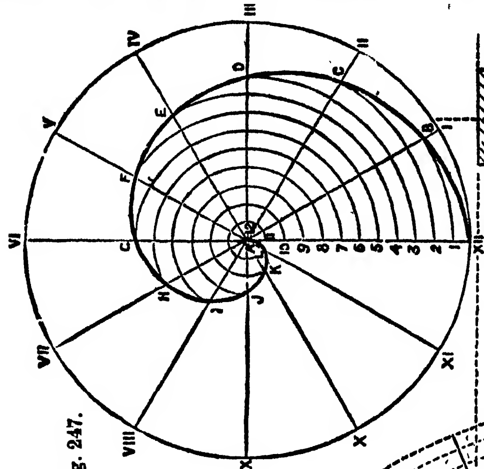


Fig. 247.

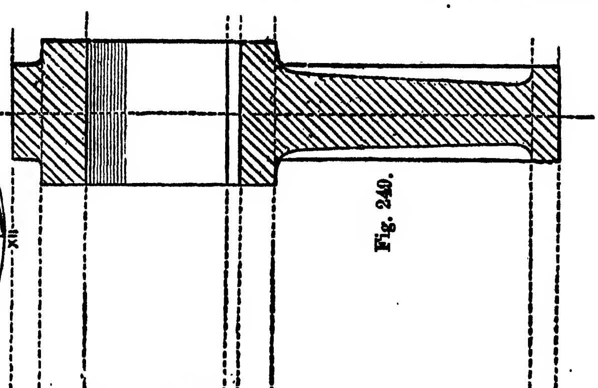


Fig. 249.

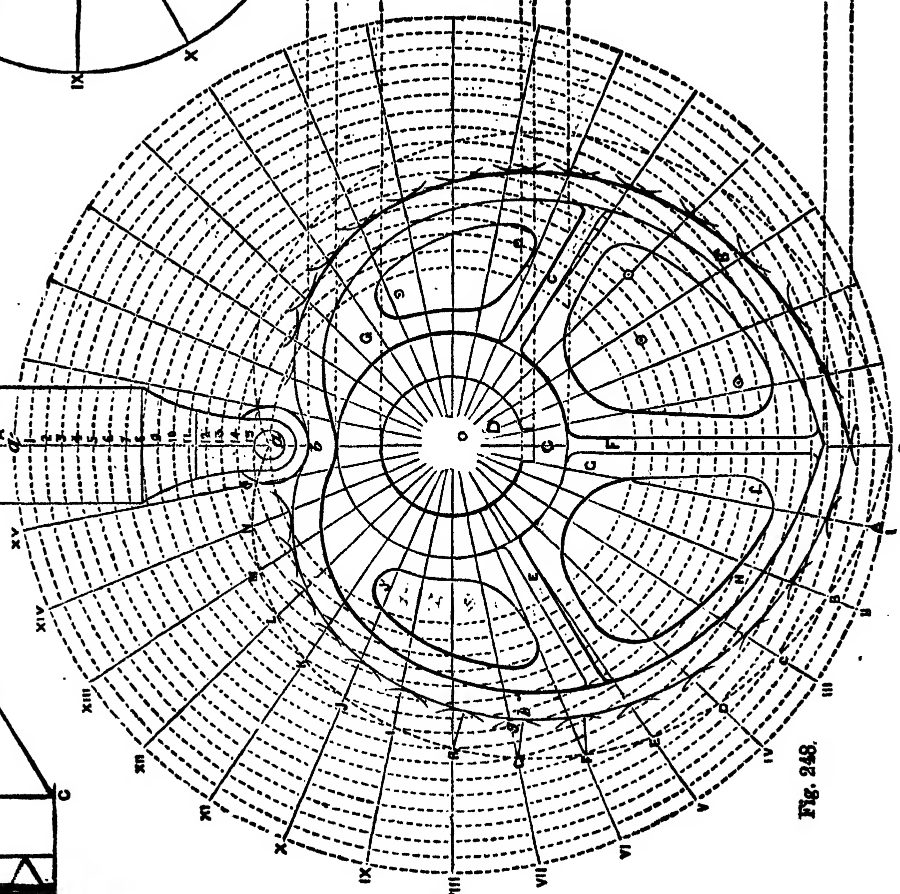


Fig. 248.

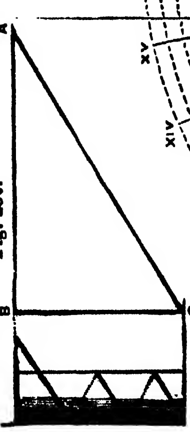


Fig. 250.

Fig. 249 is a vertical section of the cam through the centre of the shaft and the arm F.

In machines for crushing or pounding, cams in the involute form are generally used. In such cases the curve would not be a double one, its office being to raise the stamp or pestle to round the cylinder like a corkscrew. This is called the *helix*, and it is this curve which forms the thread of a screw.

The elementary steps in the construction of the helix are given in a previous lesson (page 301), and it is intended here to adapt the system to the projection of screws.

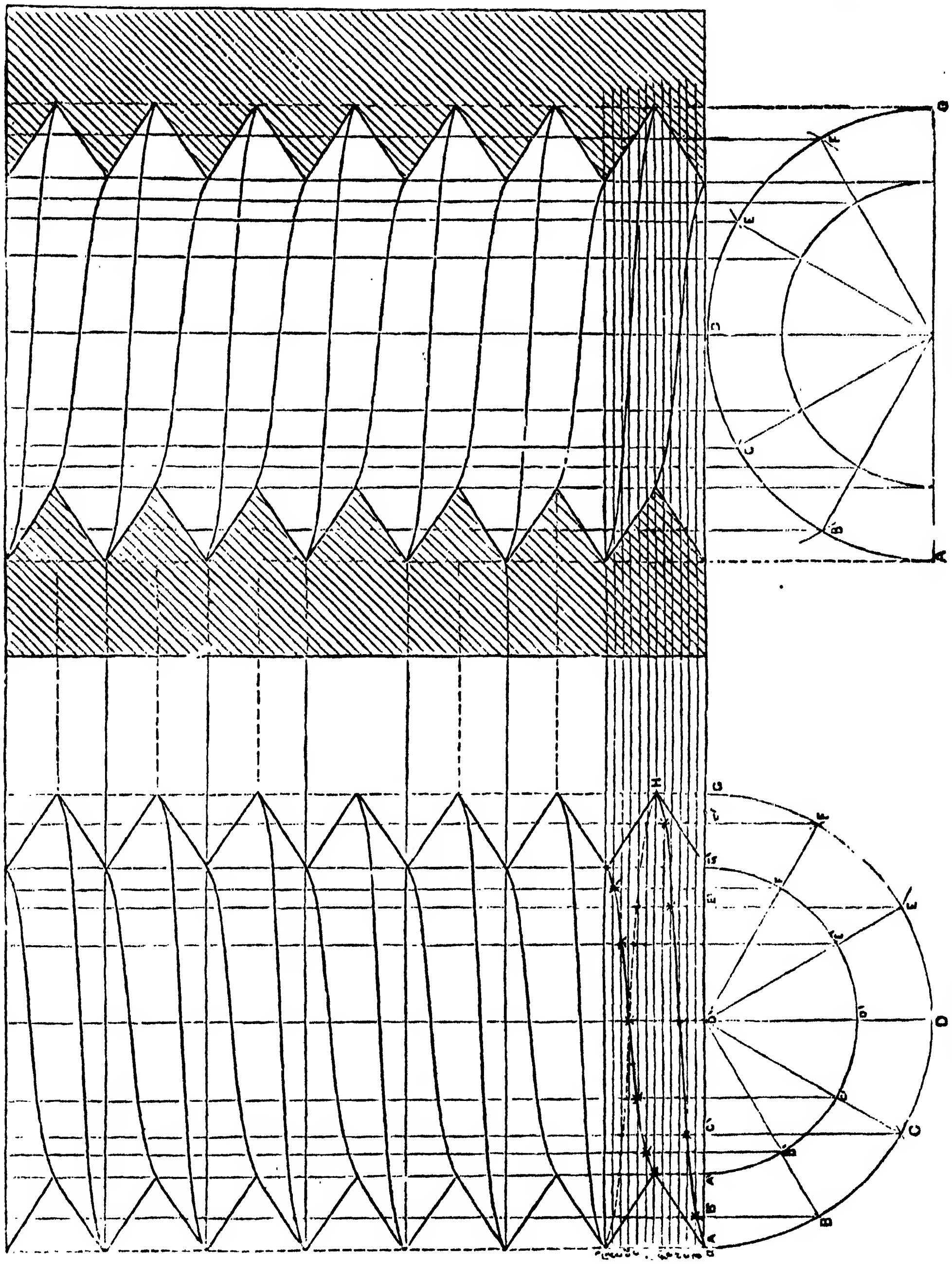


Fig. 254. Fig. 253. Fig. 252. Fig. 251.

a given height, and then letting it fall by its own weight upon the substance to be crushed, as in a stamping-mill; or to be beaten, as in a forge-hammer.

THE SCREW.

If a piece of paper of the form of a right-angled triangle (A B C, Fig. 250) be rolled round a cylinder, the hypothenuse, or long side, A C, of the triangle will generate a curve, winding

Screws are cylindrical pieces of wood or metal, in which helical grooves are cut; the ridge left standing is called the *thread*. The groove and thread together are called the *pitch*, which, as in the teeth of wheels, corresponds with the distance from the centre or edge of one thread to that of the next.

The screw then consists of two cylinders—the inner being the deepest part of the groove, and the outer being the highest part of the thread; the larger one representing the cylinder before

the grooves are cut; the other, the cylinder as it would be if the thread were completely turned off.

Screws are named according to the form of their thread—as V (or angular-threaded), square (or round-threaded).

Screws, as a matter of course, work in an aperture corresponding with the thread and grooves of the screw; this is called the *nut*, or *matrix*.

Fig. 251 is the half-plan of a V-threaded screw. The larger semicircle represents the outer, and the smaller one the inner cylinder already spoken of.

Divide these into any number of equal parts, as A, B, C, D, etc., and draw radii.

Now, devoting the attention for the present to the projection of the edge of the thread, the outer semicircle only is used.

From A and G (Fig. 251) draw perpendiculars, which will give the elevation of the outer cylinder (Fig. 252).

Now set off at A the height of a pitch, $a\ a'$, and divide it into a number of parts corresponding with those into which the circle has been divided—viz., a, b, c, d, etc.

From each of these points draw horizontals, and from the points correspondingly lettered in the plan, raise perpendiculars; these intersecting, will give the points, $\times\ \times\ \times$, through which the helix forming the thread of the screw is to be traced.

The helix for the bottom of the groove is to be projected similarly. The curve, however, must start from the horizontal g; that is, midway between a and a'.

When the first curve has been drawn, and the starting-points for the threads on the inner and outer cylinders have been found, the curves throughout may, for convenience, be drawn by means of a templet. This, however, is only to be used as a ruler, to draw the lines by mechanical means when the points have been duly projected. The draughtsman having acquired the power of drawing the curves by hand, may avail himself of the templet for expedition in making the drawings required for business purposes.

To make these templets (say the larger one), draw a straight line on a piece of veneer, and on this, starting from A, erect the perpendiculars, B′, C′, D′, E′, F′, and G.

Let the height of G be equal to G H, and make the height of each of the others correspond with the height of the intersections $\times\ \times\ \times$. Trace the curve most carefully by hand, cut it out with a penknife, and finish with fine glass-paper, slightly rounding the edges on both the front and back, so that the same templet may be used on either side. It is scarcely necessary to remark that the templet may be as wide below the line A G as may be convenient.

The V form of the thread is obtained by joining the interior angle of the groove with the angle of the thread of the screw.

Fig. 253 is the plan and Fig. 254 is the sectional elevation of the nut for this screw. It is projected in precisely the same manner, the reverse curves being strengthened. Figs. 252 and 253 may be projected simultaneously when both plans have been drawn, as the horizontals a, b, c, d, etc., may be carried across, and so serve for both figures.

APPLIED MECHANICS.—IX.

BY SIR ROBERT STAWELL BALL, M.A., LL.D.,
Astronomer-Royal for Ireland.

THE STEAM-HAMMER AND ROLLING-MILLS.

We commence in the present lesson a short account of the machinery which is used in iron-working. Foremost among the tools used in this manufacture is the steam-hammer, the invention of Mr. James Nasmyth. This machine has enabled forgings to be accomplished with facility which without its aid would have been altogether impossible; in fact, it has effected a complete revolution in the working of wrought-iron.

Before the introduction of Nasmyth's patent, the only assistance which steam had given to human labour in forging was the helve or tilt-hammer, which is still extensively used for certain classes of work. After pig-iron has been puddled, the "blooms," as the masses of iron are termed while still white-hot from the puddling furnace, are dragged to the "helve." The helve is shown in Fig. 1. It is, in reality, a lever of the first order. In the centre is the fulcrum about which the hammer turns; at one end is the heavy mass which forms the head of the hammer; at the other the power is applied; this consists of a cam (p. 408), which, by its revolutions, raises the lever, and then allows it to fall; under the head of the hammer is the anvil, on which the bloom is placed. A blow is given with every revolution of the cam, and the intensity of the blow depends upon the height to which the head of the hammer is raised. Sometimes the fulcrum is at one end of the helve, and the power is applied at the centre. In this case the machine is a lever of the first order.

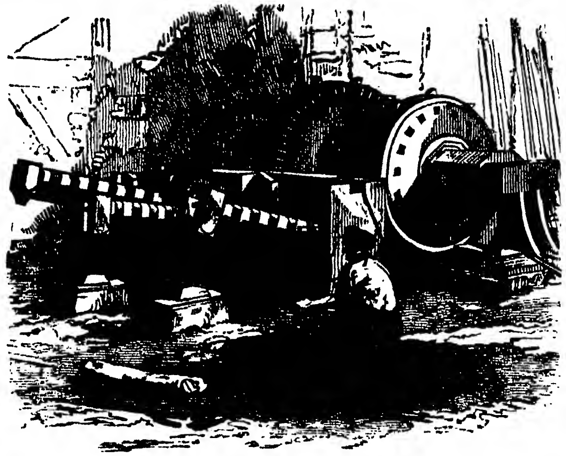


Fig. 1.—THE HELVE OR TILT HAMMER.

The magnitude of the blow which can be given by the helve, when a lever of the first order, will be understood from the accompanying figure (Fig. 2). Suppose A be the fulcrum, and that a weight at B is raised up to C, moving in the arc of a circle; the actual height to which B is raised is measured by the perpendicular C P. The number of units of work expended in raising the weight is—

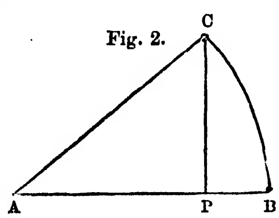
$$W \times CP,$$

where W is the number of pounds in the weight, and C P the number of feet in the line C P. Thus, for example, if C P were 2 feet and W 500 pounds, the product would be—

$$2 \times 500 = 1{,}000 \text{ foot-pounds.}$$

By the principle of work which we have already explained, the blow must perform as many units of work in its effect as were originally given to it; hence the blow must effect 1,000 units of work upon the bloom submitted to it in the case we have supposed. Suppose the bloom, which may be a mass seven or eight inches thick, receive a compression of half an inch from a single blow, then the helve must exert a sufficiently great pressure throughout that half-inch to expend all the 1,000 units of work. The pressure must therefore be—

Fig. 2.



$$24 \times 1{,}000 = 24{,}000 \text{ units of work;}$$

thus the helve compresses the bloom rather more than a load of ten tons would do if placed directly upon it.

The helve, though useful as an economical expedient for saving human labour, is in many ways an inefficient instrument. In the first place, since the head of the hammer is really moving in the arc of a circle, it is incapable of giving a flat blow to a large piece of work; the portion of the metal which is near the hinge about which the helve turns is unduly compressed, while that which is furthest away from it receives scarcely any blow. It is also not found practicable to control the magnitude of the blow, which is, therefore, always of the same magnitude. These circumstances have led to the invention of the steam-hammer, shown in Fig. 3.

A A are two upright supports of cast-iron; D is an inverted cylinder in which a piston moves; this piston is attached to

the rod E, which passes through a stuffing-box in the usual manner. To the end of the piston the hammer-head, F F F, is attached. As the piston rises and falls the hammer-head moves up and down between the vertical guides. The piston-rod is attached to the hammer by an elastic packing of wood, the object being to protect the piston rod from the effect of the blows which the hammer delivers.

The hammer in Nasmyth's original invention is allowed to fall by its own weight; the only object of the steam is to raise it. It is, therefore, only necessary to provide for the admission of steam to the lower part of the cylinder when the hammer is to be raised, and to allow it to escape when the hammer is to fall. In order, however, to control the action of the hammer with facility, and to render it self-acting when necessary, several very ingenious contrivances have been introduced, a description of which will be necessary.

At the bottom of the cylinder is a slide-valve, included in the box J. When in one position this valve admits steam to the bottom of the cylinder, and when it is moved to the other position it opens communication between the bottom of the cylinder and the external air. The rod which moves this slide is shown at L L; the other end of this rod contains a piston which slides in the cylinder M. This cylinder is called the steam-spring; it is always provided with steam in its upper part by a pipe which leads from J. Thus the constant effect of the steam is to keep the rod L and the slide-valve attached to it pressed down, and thus to keep the hammer raised. In order, therefore, to allow the hammer to fall, the rod L L must be forced upwards against the steam in the spring M. This can be done by depressing the rod P P, which is under the control of the workman in charge of the machine. When the valve is raised, the cylinder is placed in communication with the air, and the supply of steam is stopped; the consequence of this is that the hammer falls and delivers a blow upon the mass placed on the anvil, the magnitude of which depends both upon the weight of the hammer and the distance through which it falls.

Near the top of the cylinder are a number of holes. These holes discharge a twofold duty; in the first place, they enable the air to escape from the upper part of the cylinder when the re-admitted steam forces the piston upwards. When the piston attains a certain height it closes these holes, and then a cushion of air is interposed between the piston and the top of the cylinder, to prevent a collision.

The most beautiful part of the mechanism of a steam-hammer consists in the contrivances by which it becomes self-acting, so as to deliver any number of blows of any required intensity. The arrangements by which this is accomplished will be understood from the figure. The problem required may be thus stated. After a blow has been delivered, the machine must re-admit steam to the cylinder, and then, when the hammer has been raised a certain height, the valve must be closed.

Two right and left vertical screws of equal pitch are shown at U F; these screws are connected by two equal pinions, so that when the screw P is turned by the handle Q attached to the bevelled wheels, the two screws are turned with equal velocities in opposite directions, and thus the nuts are made to move parallel to each other with equal velocities. The bevelled wheel upon P slides upon it, but is prevented from turning round upon it by a feather; this is to enable the screw P P to be depressed without altering the position of the bevelled wheel. The nuts upon the screws carry the lever O O, at the extremity of which a small roller, O, is placed; now, by turning the handle at O, the

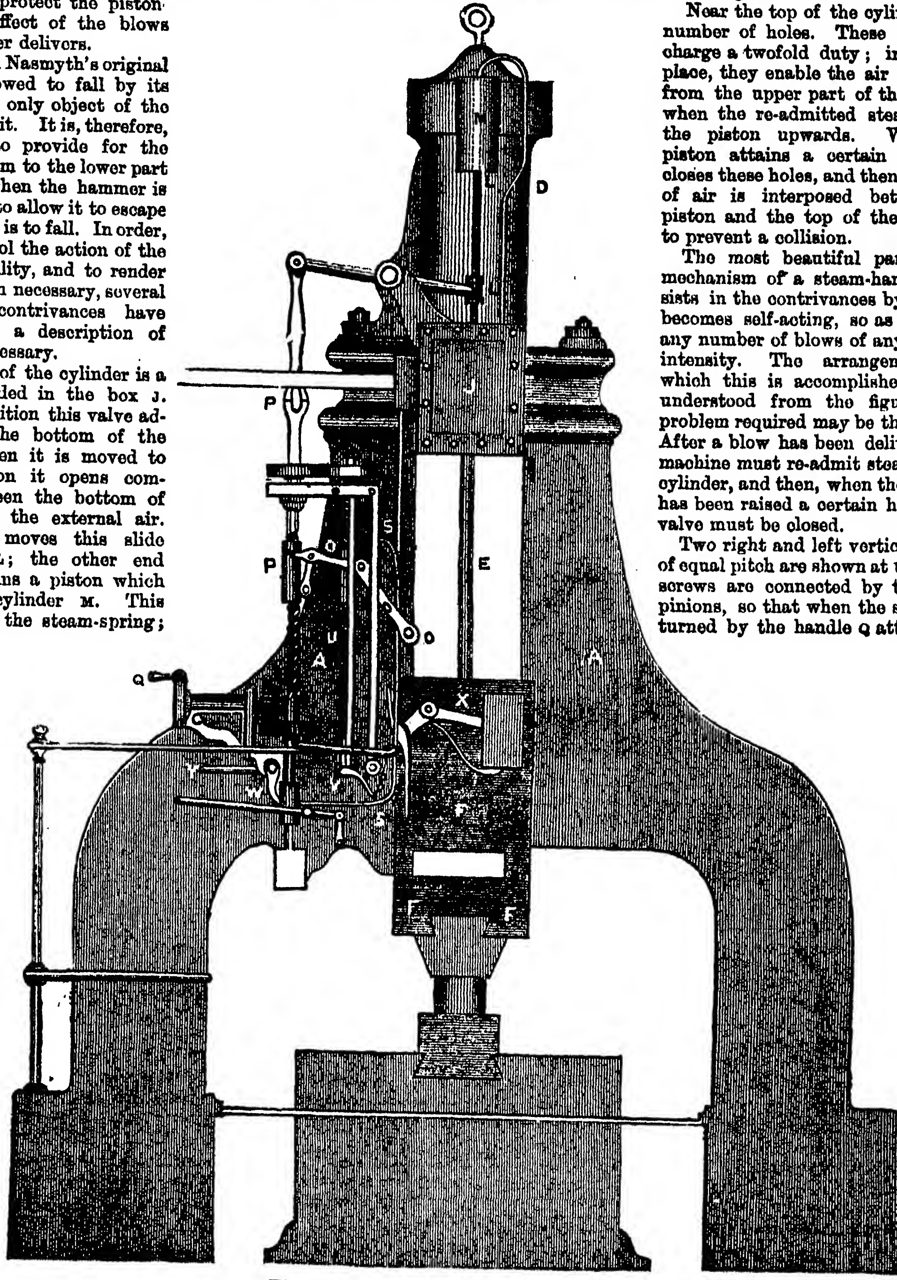


Fig. 3.—THE STEAM-HAMMER.

roller O can be placed at any height along the guides between which the hammer-head moves. When the hammer in its ascent encounters this roller, it forces it upwards; this depresses the end of the bent lever which turns on a fulcrum on the screw U, depresses P P, and closes the steam-valve. With this arrangement alone, however, the hammer could not fall to the anvil, for the moment it began to descend the action of the steam spring would open the valve, and restore the levers to their original position. An arrangement has, therefore, to be provided by which the rod D must be held up against the steam spring during the descent of the hammer. There is an enlargement upon the screw-shaft P, a little below the bevelled wheel, and there is a small trigger which, when the screw is forced downwards, drops upon the narrow portion of the shaft, and detains the screw in its depressed condition. It follows, therefore, that when the hammer has raised O, the steam-valve is permanently shut until the trigger is drawn back. An ingenious arrangement enables the hammer itself to disengage the trigger the moment the blow is struck. A piece called the latch, X, is attached to the hammer head; it is usually kept in position by a spring, but when the descent of the hammer is suddenly checked by the delivery of the blow, the inertia of the latch X carries it forward, and the end of the latch *kicks* against a piece, S S. The piece S S is capable of moving like one side of a parallel ruler; it transmits the pressure to a piece V, which then pushes back the trigger W, and allows the ascent of the screw P. In this way the hammer will deliver blow after blow, and the action is at once arrested by the attendant raising the handle at Y; the hammer then oscillates backwards and forwards, giving time for the adjustment of the work. The actual form of the steam-hammer when in use is shown in Fig. 4.

Fig. 4.—STEAM FORGING WITH NASMYTH'S HAMMER.

In the manufacture of wrought iron and steel, the rolling-mills are of not less utility than the steam-hammer. The ordinary bar and rod iron, which is used for such multitudes of purposes, is produced by rolling; and heavier masses, such as iron plates, railway lines, or armour-plating for ships, are also manufactured by the rolls. We shall commence our description of the rolling-mills by a brief account of the manner in which railway bars are made from Bessemer steel.

The Bessemer steel, after having been cast in large ingots from the "converter," soon solidifies; as soon as the ingots are set, though still brilliantly white-hot, they are seized by hydraulic cranes, raised from their moulds, and carried off to the rolling-mills. The ingots are in the form of parallelopipeds, very unlike the railway bars into which they are to be converted. These ingots are seized between a pair of rollers driven by very powerful engines; the rollers compress the ingot and elongate it; it is then passed again and again through the rollers, and gradually becomes a long bar. In the rollers are grooves, which are of the proper form to give shape to the bar; it is sent through these grooves, and finally, after passing through a series of them, it is a complete railway line. It is then, while still retaining a great deal of the original heat which it had as an ingot, carried to a saw-mill, which cuts off the ends, thus making the bar neatly finished, and of the proper length. We condense the following account of the rolling of iron from Fairbairn's work upon iron:—

"There are different kinds of rolling-mills used in the iron manufacture, and they vary considerably in their dimensions, according to the work they have to perform. The first through which puddled iron is passed are called the puddling rolls; there are others for roughing down, which vary from 4 feet to 5 feet long, and are about 18 inches in diameter; those for merchant bars, about 2 feet 6 inches to 3 feet long, and 18 inches in diameter, are in constant use. The boiler-plate and black sheet-iron rolls are generally of large dimensions; some of them, for large plates, are upwards of 6 feet long and 18 to 20 inches in diameter. These require a powerful engine, and the momentum of a large fly-wheel, to carry the plate through the rollers; and not unfrequently, when thin wide plates have to be rolled, the two combined prove unequal to the task, and the result is the plates cool and stick fast in the middle. The greatest care is necessary in rolling plates of this kind, as any neglect of the speed of the engine or the setting of the rolls results in the breakage of the latter, on the one hand, or bringing the former to a complete standstill on the other. The speed of the different kinds of rolling-mills varies according to the work they have to perform. Those for merchant bars make from 60 to 70 revolutions per minute, whilst those of large size, for boiler-plate. are reduced to 28 or 30; others, such as the finishing and guide rollers, run at from 120 to 400 revolutions per minute. In Staffordshire, where some of the finer kinds of iron are prepared for the manufacture of wire, the rollers are generally made of cast-steel, and run at a high velocity. Such is the ductility of this description of iron, that in passing through a succession of rollers it will have elongated to ten or fifteen times its original length, and when completely finished will have assumed the form of a strong wire, a quarter to three-eighths of an inch in diameter, and 40 to 50 feet in length.

"A high temperature is an indispensable condition of success in rolling. The experience of the workman enables him to judge from the appearance of the furnace when the pile is at a welding heat, so that when compressed in the rolls the particles will unite. Sometimes it is necessary to give a fine polish or skin to the iron as it leaves the rolls, but this can only be done when the iron cools down to a dark-red colour, and by the practised eye of an intelligent workman."

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